BIOLOGY FOR JUNIOR FORMS

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HAPPINESS AND FREEDOM IN NATURE

BIOLOGY
FOR JUNIOR FORMS

WITH INSTRUCTIONS FOR SIMPLE PRACTICAL EXPERIMENTS

BY

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PUBLISHERS' NOTE

BIOLOGY as a school subject has come to stay, and from the point of view of the educationist it is a most welcome guest. Armed with the recommendations of reports from the Science Masters' Association, the Spens Report and the published views of other authoritative individuals and groups, the educationist will see that the maximum benefit will be derived from the new arrival. But it is the teacher who has to do the fundamental work, much of which is of a pioneer nature at present. So for that reason, the guest is proving a difficult problem to many teachers. This applies to teachers who are trained biologists ; but many of them are not even that, so all, and especially the latter, must look to books for guidance.

Miss M. R. Lambert, science teacher in the West Oxford Senior School, has just completed a Senior School course in biology in three books. Each book covers a year's course, and since the concentric method is adopted, the first book can be used with advantage in Junior Schools also, and the third book will be found useful in the junior forms of Secondary Schools.

Macmillan's have also just published *A School Course of Biology* by L. J. F. Brimble, author of *Everyday Botany* and *Intermediate Botany*. The *School Course* is written for the School Certificate and Matriculation forms. Since Miss Lambert's series of three books have proved so successful, the publishers have decided to publish her Book III as a separate book entitled *Biology for Junior*

Forms. Their decision was made for two reasons: (1) Miss Lambert has adopted the concentric system so that Book III is a course complete in itself; (2) this book can be used with profit in the junior forms of Secondary Schools, and thus lay an admirable foundation for School Certificate biology which follows, and which can very safely be based on Mr. Brimble's book. The two books, *Biology for Junior Forms* (Lambert), and *A School Course of Biology* (Brimble) can be warmly recommended to satisfy all the requirements of the Secondary School student throughout his studies terminating the School Certificate stage.

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CHAPTER I

BIOLOGY

THE STUDY OF LIFE

BIOLOGY is the study of life, both plant and animal. Years ago, little was known about the structure, behaviour and nature of living things; but nowadays biologists know much more about plants and animals. They have observed their structure, watched their habits and tried to understand their natures. With the help of the microscope, X-rays and other apparatus, they have learned how most living creatures are formed, how they breathe, how they are nourished, how they grow, and how they produce more living things like themselves. From their observations, scientists know how most creatures are equipped to meet their enemies as they go through life and how each is armed to defend itself against them. They have also discovered how living things are protected against the varying weather conditions and how they adapt themselves to these changes and to their environments. They have observed, too, how all are endowed by Nature with the power to resist and overcome disease, how they provide for themselves food and shelter in the time of need, and how the balance in numbers of the various animals and plants is maintained.

As a result of this knowledge, thoughtful people of to-day show a kindly spirit towards plants and animals. They cultivate more flowers and appreciate them for

E. J. Burrell

Fig. 1. A wounded cat bandaged at the P.D.S.A.

their beauty. They show more care for animals too, and realize their attractiveness, their powers of intellect, and that all, though they cannot speak, are sensitive to pain. Much thought and help are given by kind people to prevent neglect and suffering of animals. In many towns to-day there are clinics and hospitals where sick and injured animals may have treatment free of charge, if their owners are poor people (Fig. 1).

A Living Machine

The natural world is composed of countless plants and animals, each one differing from all others in age, form, size, colour or in some other detail, while they all make a long, living ladder, showing every degree of development. In the first group of animals, for example, are the *Protozoa*, the simplest of all living things (Fig. 2). These are microscopic creatures consisting of only one cell.

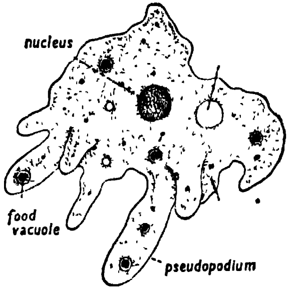


Fig. 2.
Amœba, a unicellular animal

The simplest plants also consist of one cell only (Fig. 3). In the top group of animals are the *mammals*, the most advanced animals, composed of millions of minute cells. Between these very simple and most complex forms are millions of other creatures in every stage of development.

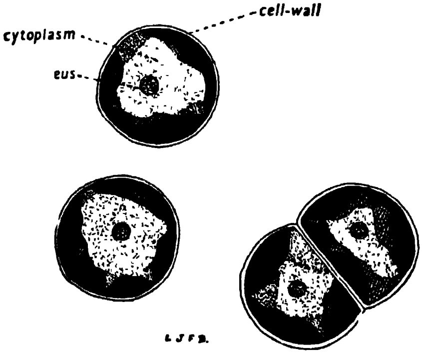


Fig. 3. *Pleurococcus*, a unicellular plant

In Nature the *cell* is the smallest unit of any living creature. It consists of a semi-fluid living material known as *protoplasm* (usually divided into two parts,

namely, the *cytoplasm* in which the *nucleus* is embedded); and cells, of similar shapes and sizes grow together, forming the different *tissues* which make the various parts of plants and animals. In a tree the main parts are the root, stem, leaves and flowers; in a mammal they are the head, body, limbs and internal organs. Every cell of every part of these wonderful living structures has its own particular place, and all work together and in harmony. In this way a living creature resembles a machine.

In a well-built engine, all the wheels, bolts, springs, nuts and screws are carefully assembled, so that each part, however small, may serve some purpose and do its share of the work. The engine, however, is not alive and so cannot start working by itself. To be set in motion it must have some kind of power supplied either by some form of fuel, such as coal or oil, or by electricity, water-pressure or compressed air. All these are sources of power and possess in themselves energy which the engine needs and uses to do its work.

Coal is a fuel possessing within itself energy which it absorbed from the sun, long ago, when it was growing as a tree, and which it has stored up ever since. When coal burns, the energy is set free in the form of heat; but this fuel cannot burn without oxygen from the air. As the coal in the engine burns, the heat energy is liberated and passes into the boiler where it converts the water into steam. This exerts a great pressure and thus makes the engine work.

Living "machines", however, provide their own power to set them in motion. They are endowed by Nature with that mysterious force known as *life*. The

living machines also have work to do. They must perform certain functions so that they may keep themselves alive, and so that they may be able to pass life on to their young. To do this, plants and animals must have continuous energy and this they obtain from their food, just as energy for the engine is obtained from its fuel.

Each living creature requires its own particular kind of food. The various types of plants need different kinds of mineral salts, and some animals are flesh eaters, others feed on plants. Most plants absorb their energy directly from the sun and animals which live on plants get this same energy, because it is stored in their vegetable food, while flesh-eating animals also obtain their energy stored in their animal food. All living things, therefore, obtain their energy either directly or indirectly from the sun.

Every kind of food contains energy. During the process of digestion this is liberated and keeps all the parts alive and in motion. Moreover the food digestion cannot go on unless supplied with air containing oxygen obtained during respiration. Oxygen brings about the chemical change and sets the energy free and this enables the living machine to do its work.

There are obviously some very important differences between living and non-living machines. All young living things under natural conditions have the power to grow into bigger ones ; but an engine cannot grow. Most living creatures also are able to heal themselves when they are slightly injured. In fact, some animals can even grow new limbs. If a crab loses a claw it will grow another ; if a certain, simple type of worm has its tail cut off another will grow.

There is yet another and still greater difference between

a living creature and a lifeless engine. All living creatures have the power to make more living creatures like themselves. Sweet peas produce seeds from which grow more sweet peas; robins lay eggs from which hatch young robins; dogs produce puppies which grow into dogs like themselves; human beings have children, who grow up into adults resembling their parents. That is, living things *reproduce* themselves. Non-living things cannot do this.

QUESTIONS ON CHAPTER I

1. What is meant by the natural world?

2. In what respects is a plant or an animal like a perfectly constructed machine?

3. What are the obvious differences between a living creature and an engine?

4. From what sources do engines obtain their energy?

5. How does a living creature obtain its energy so that it may fulfil its purpose in Nature?

6. Explain the statement that all living things obtain their energy from the sun.

7. Compare the use of oxygen by an engine and by a dog.

8. How far may coal for a steamship be compared with bread for man?

CHAPTER 2

THE LIFE OF A GREEN PLANT

Division of Labour

There are thousands of kinds of green plants. Some of these are so minute as to be invisible without the aid of the microscope ; others are so large that they rise above the highest spires and weigh many tons. Some are so simple in form that they are only single cells consisting of protoplasm and a nucleus ; others are formed of a number of such cells ; while a large variety of plants are composed of a variety of cells.

All plants begin their existence from germs as *embryos* and then build themselves up until they become full-grown plants. In order to do this they must have food, which they *manufacture* from water and mineral substances collected from the soil, and carbon, which they get from carbon dioxide out of the air.

Though most plants do not move about, many of their activities and processes correspond to those in the lives of higher animals and even of ourselves. They absorb air containing oxygen ; they absorb water ; and they absorb food which they change into material like themselves.

Many plants, just as many animals, grow from embryos formed by the union of the male and female *germs*. In their development they pass through the stages of in-

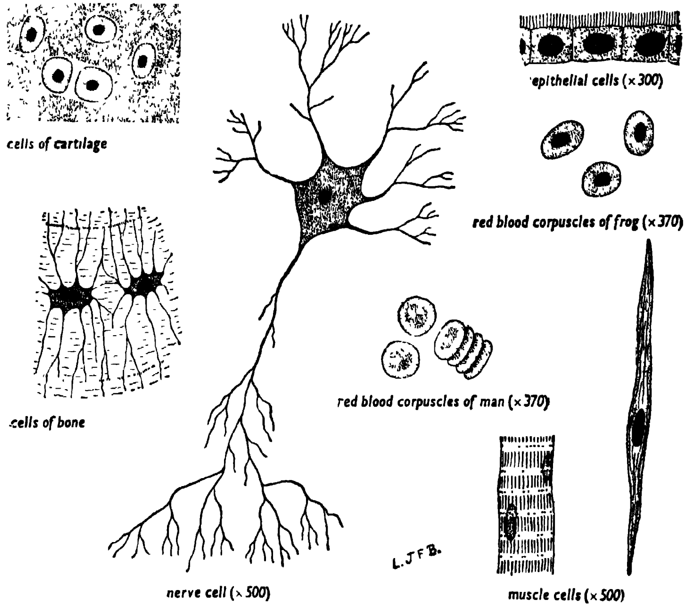


Fig. 4. Types of animal cells

fancy, youth and on to maturity, when they are capable of producing new plants.

If you examine on the screen from a microprojector sections, cut from the various parts of a plant, you will find that they are composed of a variety of cells. Some are spherical, some roughly cubical, some have many sides. Some of them consist only of a nucleus and protoplasm; others also contain food reserved there for the plant; while others contain substances either to attract or repel insects and other animals (Fig. 4).

Most plant cells are enclosed in a *cell-wall* and they

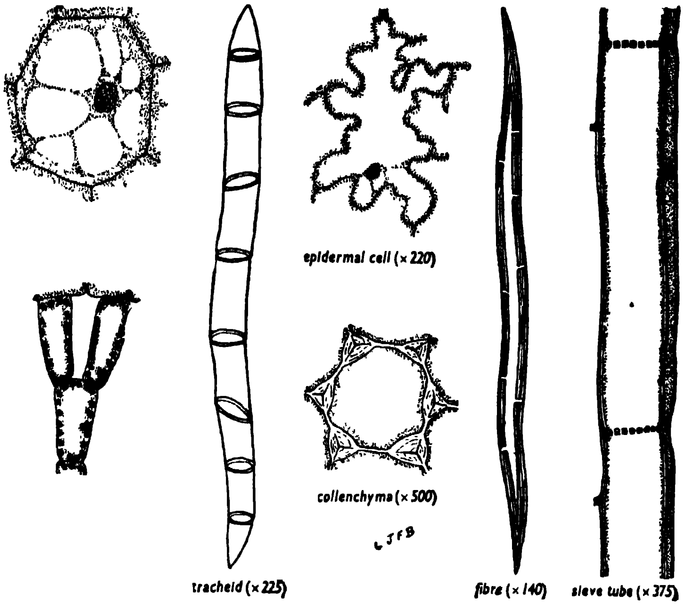


Fig. 5. Types of plant cells

take different shapes to fit them for the particular work they have to do (Fig. 5). Some cells in the root and stem, for example, are shaped like cylinders and placed end-on-end to form long tubes, so that the food materials from the soil may pass through them to the leaves. Some cells forming the leaves are spherical ; others offer a large surface area to receive rays of light from the sun ; while others are oblong and stand on end so close together as to resemble a fence or palisade. Cells are grouped together in the living creature according to the kind of work they have to do. These groups of cells are called *tissues*.

Observations

Examine on the screen from the microprojector sections cut from the (*a*) root, (*b*) stem, (*c*) leaves of a green plant.

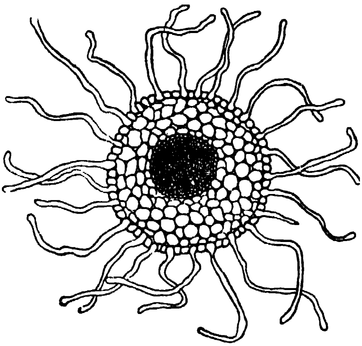


Fig. 6. Tissues of a root seen in transverse section

Notice: (1) the many kinds of cells forming the tissues; (2) the shapes of these cells; (3) the contents of the cells (Figs. 6, 7 and 8).

The body of an animal and of man too, is made up of tissues, though the cells are different from those of plants, for example. they have no cell-walls. They, too, are of various kinds and so form the different organs and limbs of the creature. One kind forms the lungs, another the kidneys, another the heart, another the brain and so on. Every cell, however small, in the world

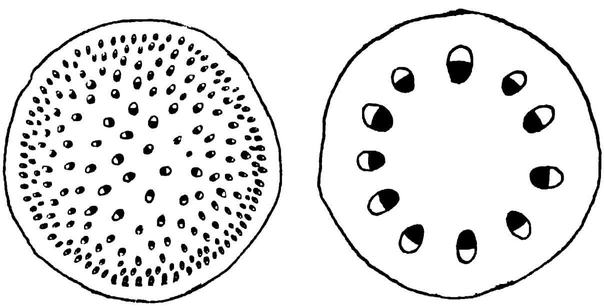


Fig. 7. Tissues of a monocotyledon (left) and dicotyledon (right) stem seen in transverse section

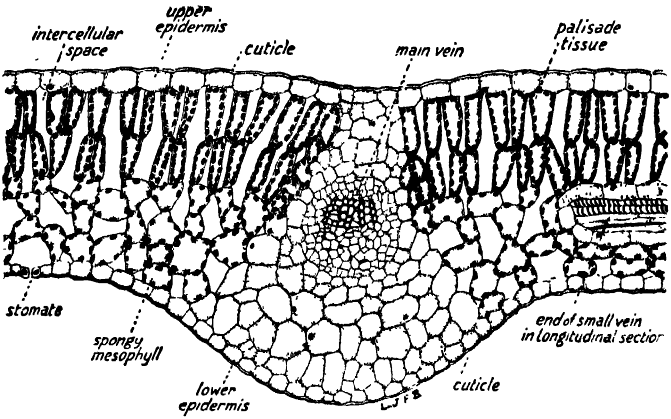


Fig. 8. Tissues of a leaf seen in transverse section

of Nature, serves some purpose. The heart pumps the blood through vessels to every part of the body. You can feel the regular heart beat or pulse in your wrist, as the blood is driven in waves through the artery just below your fingers. If you press your hands on your sides you can feel the regular movements of your ribs, as your lungs expand and contract in breathing. In a similar way all the other organs of the body work in harmony in a healthy person.

The activities of a plant are similarly shared by its parts. The flowering plant must be nourished so that the seeds may be brought to perfection, because, through the seed, life must be passed on. In Nature, this is the aim and purpose of every living creature, and the labour involved to accomplish this end is divided among all the cells in its structure.

Simple experiments will show the share of this work allotted to the main parts of a plant.

Roots

(1) It is obviously the function of the root to fix the plant firmly in one place.

(2) The root is also responsible for providing the plant with certain raw food materials obtained from the soil.

(3) The roots of some plants, turnips and carrots for example, store manufactured food for future use.

(4) Some roots, ivy for example, help the plant to climb to get as much air and sunlight as it can.

Experiments

To show that roots take in moisture

(1) Through a hole in a cork pass a bean seedling so that its roots dip into water coloured with red ink—in a test-tube. Mark the level of the liquid with a strip of paper and stand the tube in the sunlight. After a few days notice the level of the liquid.

Result. The level is lower. This experiment shows that the water has been taken in by the roots.

(2) Cut across the root of the seedling. Squeeze the end gently and notice that the red liquid comes out of the cut surface.

(3) Cut very fine sections and examine them on the screen from the microprojector. It will be noticed that some cells contain the red liquid. These cells therefore are those used for transporting the food materials from the soil.

STEMS

The stem of a plant is responsible for important work also.

(1) The stem holds the leaves up to the light and air which are essential to the life of the plant.

(2) The stem supports the flowers and fruit.

(3) The stem conducts the raw materials, collected by the roots from the soil, up to the leaves, where they are manufactured into food.

(4) The stems of some plants which remain under the surface of the soil, potatoes for example, store manufactured food for future use.

Experiment

To find the water paths through the stem to the leaves

Cut very fine sections through the stem of the bean seedling and examine them on the screen from the micro-projector. The cells containing the red liquid should be clearly seen. Evidently these cells conduct the raw food materials to the leaves, and are grouped together into what are called *vascular bundles*.

LEAVES

The leaves of some plants have a comparatively short existence, so they must be very active while they are alive, for they are responsible for a very large and important share of the work of the plant.

(1) The leaves are the chief parts of the plant through which it takes in oxygen and gives out carbon dioxide

in the process of *respiration.* Most plants, however, respire a little through all their parts.

(2) The leaves are the food factories. They receive the water and raw materials from the soil conveyed through the stem and also carbon from carbon dioxide which they themselves take in from the air. All these they change chemically and manufacture them into sugar, a form of food which can then be used by the plant. To do this the leaves need the help of sunlight. This process is known as *photosynthesis.*

(3) The leaves give off the water which the plant no longer needs. The raw mineral food taken from the soil is dissolved in water and travels up to the leaves in solution. When it gets there much of the water is no longer required and so this excess passes out of the leaves in the form of water vapour. Thus plants give out this waste liquid in the form of vapour through tiny holes, called *stomata,* which are usually on the under surface of their leaves. This process is known as *transpiration.*

Experiments

1. Plants respire through their leaves

Cover with a bell-jar a geranium in a pot and a test-tube containing lime water. Leave them in a dark room for a few hours.

Result. The lime water turns cloudy due to the excess in the jar of carbon dioxide which must have been given out by the plant during respiration.

2. Leaves give off excess water

Plant a young cabbage in a flower pot. Cover the pot and soil with oil cloth so that no moisture can escape.

Place the whole pot and plant under a bell-jar, and arrange a second similar jar but without the cabbage.

Result. After a short time a mist forms on the inside of the jar with the cabbage and later tiny drops of water appear there too. The other jar remains dry. The moisture has been given off through the leaves of the cabbage since none appeared on the empty jar.

3. Excess water is given off through the stomata

Repeat the above experiment, but using a geranium plant. First smear the undersurface of the leaves with vaseline.

Result. Only a very little mist appears on the jar because the stomata are blocked and moisture cannot get out.

Flowers

The flower is the part directly responsible for actually forming the seed.

A complete flower has a *calyx*, *corolla*, *stamens* and *pistil*. The calyx, the outer part, composed of *sepals*, entirely surrounds the other parts when the flower is a bud and in that way protects them from cold and rain. The corolla, formed of *petals* usually brightly coloured and highly perfumed, attracts insects and other small animals to the flower. They suck the nectar and other sweet juices they find there and carry away the *pollen* which sticks to their bodies. When these insects visit another flower, this pollen may be rubbed off there. The stamens produce the pollen which appears as yellow, dusty powder, but in reality, each grain of pollen contains the male germ of life. The pistil in the middle of the flower contains the

eggs. These are produced within small structures called *ovules* in the swollen part at the bottom called the *ovary*, and each awaits a male germ of life from a pollen grain to join it. When the egg is thus fertilized it forms an *embryo* and starts the life of another plant which develops in the ripened ovule or seed. The ovary itself, with the seeds inside, usually becomes the *fruit*.

Observations

Sow sweet peas and seeds of other annuals in boxes or in the garden. Observe how they germinate, grow through the stages of infancy, youth and on to maturity. Notice how they then form their seeds in which life is passed on to the next generation. After this their own life-cycle is finished, and soon to them come death and decay. In the process of decomposition, tissues are broken down, carbon dioxide is given back to the atmosphere and the mineral substances again return to the earth.

QUESTIONS ON CHAPTER 2

1. What do you understand by division of labour in the life of a plant?
2. What share of this work is undertaken by the root of a plant?
3. Describe an experiment to prove that roots absorb moisture.
4. Describe the chief functions of the stem of a plant.
5. How could you prove that water passes through the stem to the leaves?
6. What are the chief functions of the leaves of a plant?

7. Describe an experiment to show that plants respire through their leaves.

8. What is the process of transpiration?

9. Name the chief parts of a complete flower.

10. Describe the work of each part.

11. Where and how is a seed formed?

12. Which part of the flower usually becomes the fruit?

CHAPTER

HOW PLANTS OBTAIN RAW FOOD MATERIALS

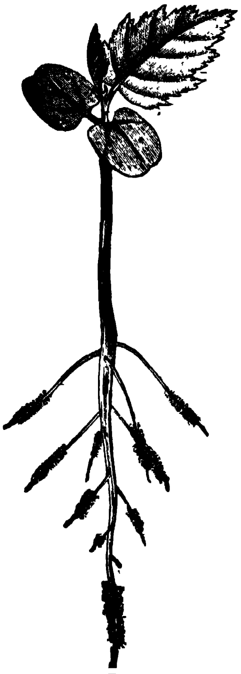


Fig. 9. Seedling of hornbeam. Note the root hairs

PLANTS collect various raw materials which they manufacture into food for their own nourishment. Part of the materials they obtain from the soil, the rest they get from the air. Those taken from the soil consist of water and mineral salts soluble in water, while carbon is taken from carbon dioxide, one of the gases of the atmosphere.

Water is needed in the food-manufacturing process. It is not only used as an ingredient, but is also helpful in transporting the other raw materials from the soil to the factory. Some plants require a larger amount of water than others.

ABSORPTION OF WATER

If you examine the end of a root through a lens, you will see that it is covered with very fine *root*

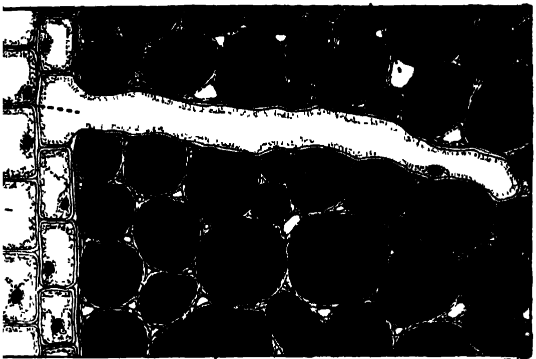


Fig. 10. Part of a root enlarged showing how a root hair grows into close contact with soil particles

hairs. These little hairs absorb the water and in this way they are the real collectors of the raw materials from the soil (Fig. 9).

Each root hair is composed of one long cell with a very thin cell-wall lined with protoplasm, which is a thick fluid. By close contact with the soil particles water is drawn in through the cell-walls of the root hairs (Fig. 10).

In Nature it is common to find many substances that have an attraction for some other substances and are drawn into contact with each other. Some have a greater attraction or *suction pressure* than others, and so these draw the lesser towards them, as a magnet attracts a needle. In plant life the cell contents of the root hairs have a greater attraction than the moisture in the soil containing dissolved mineral salts, so that the weaker

solution is drawn into these cells. In this way the water and mineral salts do not enter the plant through an opening, but are actually pressed in through the walls of the root hairs. This form of pressure or attraction by which a liquid is forced towards another is known in science as *osmotic pressure*. For this reason the process, by which the water, containing dissolved mineral salts, enters the plant through the walls of the root hairs, is known as *osmosis*.

Experiments

1. To show how soil water enters a plant

Apparatus. A few raisins with stalks, and gooseberries, dish of water. Place a few raisins and gooseberries in a dish of water.

Result. After a few hours they begin to swell because the denser fluid inside has drawn in some of the water through their skins.

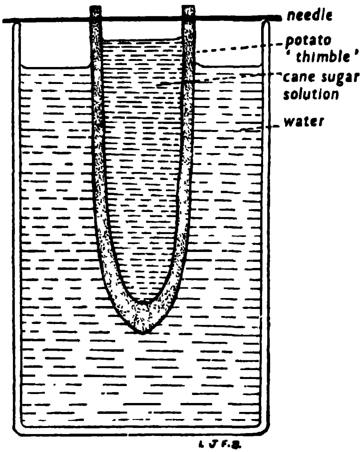


Fig. 11.
Apparatus for demonstrating osmosis

2. To demonstrate osmotic pressure

Apparatus. A potato, cane sugar, saucer of water.

Cut a potato into the shape of a large thimble. Hollow out the middle and suspend it in a beaker of water. Make a solution of

cane sugar and pour a little in the thimble. Colour the sugar solution with red ink (Fig. 11).

Result. After a time the level of the sugar solution in the thimble rises which shows that some of the water must have passed in.

3. To demonstrate the process of osmosis

Apparatus. Sheep's bladder, thistle funnel, beaker of water.

Cut a piece of sheep's bladder from one which has been inflated and dried. Soak it in water to soften it then bind it over the end of a thistle funnel with rubber bands. Pour in 10 per cent salt solution and invert the funnel in a beaker partly filled with water. Make the level of the solution the same as that of the water (Fig. 12).

Result. After a few hours the level of the solution rises because it has drawn in some of the water through the membrane.

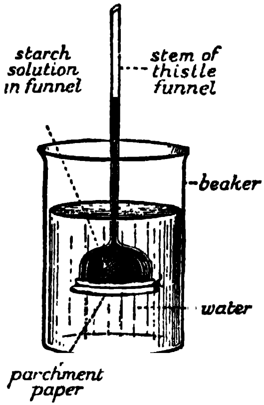


Fig. 12. Experiment for demonstrating osmosis

4. To make an osmotic cell

Apparatus. Sausage skin from a butcher, starch, iodine.

Fill a sausage skin with water containing a little starch. Tie the ends firmly and suspend it in water coloured with iodine.

Result. The iodine passes through the membrane into the starch solution and causes a change of colour.

Food Channels and Water Paths

Once absorbed into the root these solutions pass up into the stem and to the leaves. The special channels through which they travel are long tubes grouped together, forming the *vascular bundles* which you have observed on the screen in the sections cut from the root and stem of a plant.

The wood cells of the vascular bundles, forming the paths along which the liquid flows, may be seen in the stem of a herbaceous plant which has been placed in coloured water.

Experiments

5. To show the water paths up a stem to the flower

Stand the stems of snowdrops or white sweet peas in water coloured with a few drops of red ink. In a day or so red streaks appear in the petals, and these are the water channels.

Root Pressure

This upward flow of raw liquid food is known as root pressure, and it is often called by the practical gardener the 'rising of the sap'.

6. To demonstrate the rising of the sap

Cut through the stem of the groundsel kept in coloured water and the red liquid will exude from the cut surface.

7. To demonstrate root pressure or the rise of the sap

Apparatus. Potted plant, glass tube, rubber bands.

Cut through the stem of a healthy young plant in a pot. Attach to the stump end a glass tube by means of rubber bands. Stand the pot in a bowl of water and support the tube with an iron stand. Pour a little water down the tube and then a drop of oil which will float on the water and prevent evaporation (Fig. 13).

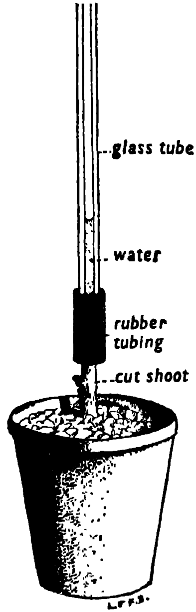


Fig. 13. Apparatus for demonstrating root pressure

Result. The oil-level rises in the tube because it is pressed upwards by the rising sap due to root pressure. The process of root pressure varies according to soil and weather conditions. In spring it is most active, for at this time buds and leaves are developing. Then the sap rises quickly and the raw materials are rushed to the leaves and manufactured to supply the young growing parts with nourishment.

QUESTIONS ON CHAPTER 3

1. What raw materials are used by a plant for manufacturing its food? Whence are they obtained?

2. Why does a plant need water?

3. Draw and describe the root hairs you have seen enlarged on the screen from a microprojector.

4. What is meant by osmotic pressure?

5. Describe an experiment to show how root hairs absorb soil water by the process of osmosis.

6. How could you find the water paths in the stem of a herbaceous plant?

7. How do raw materials from the soil reach the leaves at the top of a tall tree?

8. What is meant by root pressure?

9. Describe an experiment to show the rise of the sap in the stem of a plant.

10. When and why is root pressure most active?

11. Why does root pressure vary with weather and soil conditions?

12. What are vascular bundles?

CHAPTER 4

HOW PLANTS MANUFACTURE THEIR FOOD

THE raw materials from the soil reach the leaves where the plant manufactures its food. Mineral salts dissolved in water have been collected by the root hairs, pressed up the stem and spread out through the veins into the cells forming the blades of the leaves. Much of the water which has conveyed them is no longer needed and passes out of the plant as vapour through the pores or stomata in the leaves. A certain amount, however, is retained, because it is required in the food-manufacturing process. Carbon also is needed, and this is obtained from carbon dioxide which the leaves take in from the air. Here the raw materials from the soil combine with carbon from the air and are manufactured chemically into food which can be digested and turned into living plant substances.

This chemical change, however, can not be brought about except under certain conditions. The leaves must be green and must have sunlight. Therefore the manufacture of foods from the raw materials, with the aid of light, is called *photosynthesis*. Then, provided with these conditions, the salt solution is distributed in the cells of the leaves which turn themselves to get as much sunlight as they can. Soon these raw materials become changed. The carbon dioxide separates into carbon and oxygen and the carbon combines with the

hydrogen and oxygen of the water to form first sugar and then, in most cases, starch and other *carbohydrates*. From the same elements, *fats* are also made. The carbon, together with hydrogen and oxygen from water, unites with certain elements from the mineral salts (chiefly nitrogen) to make *proteins*. During these changes the oxygen from the carbon dioxide returns to the atmosphere.

On bright sunny days the leaves are especially active and make more food than the plant requires for use at once, so that after sufficient has been supplied to all the opening buds and other growing parts, the amount left over is safely stored away for future use. Some is stored in the roots, some in the stems, some in special storage organs and some in the *cotyledons* in the seeds ready to feed the young plant there, when it begins to grow.

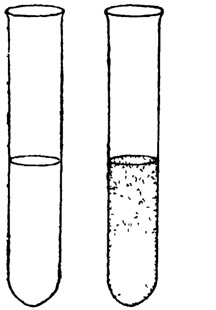


Fig. 14. A test for starch

Experiments

1. To test starch with iodine

Apparatus. A piece of starch, test-tube, iodine solution.

Pour a little water on a piece of starch in a test-tube. Shake it well and notice the white colour. Add about five drops of iodine solution and shake again (Fig. 14).

Result. The colour changes to purplish-black. Hold the end of the test-tube in the Bunsen flame. The colour disappears. Then cool the test-tube in cold water. The purplish-black colour returns.

2. To test for starch in leaves

Apparatus. Two or three green leaves picked from a plant growing in the sunlight, alcohol or methylated spirit, iodine solution, test-tube.

First dip the leaves in boiling water to kill them. Next soak them in methylated spirit to extract the green colour. Then put them in water with a few drops of iodine.

Result. The colour of the leaves changes to purplish-black, because they contain starch in their cells.

3. To show that light is necessary for making starch

Pick two or three leaves from the plant which has been kept in the dark cupboard for a few days, and repeat Experiment No. 2 to test for the presence of starch.

Result. There is no change in colour when the leaves are treated with iodine, because they contain no starch in their cells.

From these experiments we learn that the starch prepared by the plant in the sunlight was used up by it in the dark, and that light was necessary for the plant to make some more.

4. To show that light is necessary for making starch

Cut a pattern or your initials in two pieces of brown paper. Fasten between them a leaf still growing on a plant, so that only the part made by the pattern is exposed to the light. After a few days pick off the leaf and test it for the presence of starch (Fig. 15).

Result. Starch is resent only in that part of the leaf which was exposed to the light, and this forms the design in the leaf in a purplish black colour.

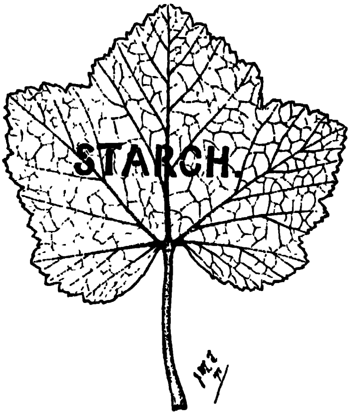


Fig. 15. A leaf which had been covered with brown paper (which had the word "starch" stencilled on it) and after exposure to light tested for starch

Starch consists of hydrogen, oxygen and carbon combined together in certain proportions of each of these elements. Water consists of two parts of hydrogen and one part oxygen, so for the manufacture of starch plants get their hydrogen and oxygen from water taken in by the roots. It can be shown by experiments that they obtain the carbon from the atmosphere.

5. To show that carbon is necessary for making starch

Apparatus. A plant in a pot, caustic soda solution, a large bell-jar and soda lime.

(*a*) Covei with a bell-jar a growing plant in a pot and test-tube containing caustic soda solution. Through the cork connect a U-tube containing soda lime as shown in Fig. 16. Stand the whole apparatus in the sunlight.

Caustic soda is a substance which is capable of absorbing carbon dioxide. The solution in the tube, therefore,

will absorb the carbon dioxide in the jar. The soda lime in the U-tube prevents more of this gas from coming into the jar. Thus the carbon supply is cut off from the plant.

After a few days test the leaves of the plant with iodine for the presence of starch.

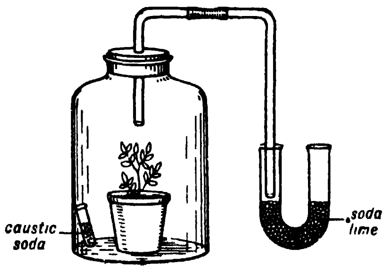


Fig. 16. Plants obtain carbon from the air

Result. There is no starch present in the leaves. This experiment shows that starch cannot be made by the plant without carbon dioxide.

(*b*) Repeat the above experiment, this time using cotton-wool in the tube instead of soda lime.

Result. After the same length of time, test a leaf for the presence of starch. It will be found that iodine turns the leaf purplish black because starch has now been made in the cells. *N.B.*—In both these experiments (*a* and *b*) the plant should be kept in a dark cupboard first until there is no starch in the leaves.

Carbon dioxide, you will remember, is one of the gases of the atmosphere. It is given off when most things burn, and it is *exhaled* by all living organisms during *respiration*. The gas consists of carbon and oxygen combined together in the proportion of one part carbon and two parts oxygen. During their food-manufacturing process, plants split up this gas into its two elements, carbon and oxygen. They keep the carbon for their own use, but the oxygen is returned to the air.

6. To show that plants return oxygen to the air.

Apparatus. Canadian pondweed, funnel, test-tube, trough of water.

Place sprigs of pondweed under a glass funnel in a trough of water, and invert a test-tube filled with water over the funnel as shown in Fig. 17. Care must be taken to keep the water in, so the thumb should be placed over the mouth and not removed until it is below the water in the trough. Stand the whole apparatus in the sunlight.

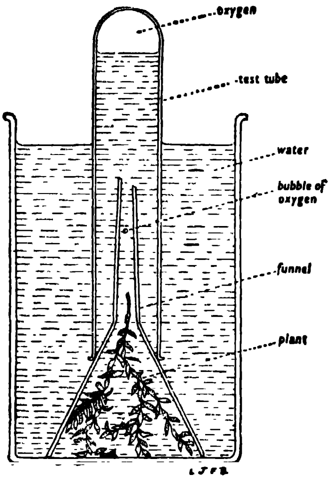


Fig. 17. Plants give off oxygen

Results. (*a*) Bubbles of gas from the pondweed will rise to the top of the tube and slowly drive the water out. Test this gas. Carefully remove the test-tube and insert a glowing splinter.

(*b*) The spark burns more brightly and this shows that the gas in the tube is oxygen.

In these experiments light is needed by green plants to split up carbon dioxide, so that they can use the carbon for making starch.

Equally as important as sunlight for plants to manufacture their food is the condition that the leaves themselves must be green in colour. If leaves which are not green are treated with iodine, it will be found that there is no starch in their cells. This important substance

which gives the green colour to plants is known as *chlorophyll.* This substance is also present in other plant organs, such as young stems.

7. To show that chlorophyll is necessary for food manufacture

Apparatus. Green leaves, variegated leaves, flower petals, toad-stools, three flasks.

Fix up the experiment by placing each of these specimens in a flask and cork tightly: (1) green leaves, (2) variegated leaves, (3) flower petals and toad-stools.

(*a*) Stand the three flasks in a sunny window. After a time insert a glowing splinter in each.

Results. (1) Shows the presence of oxygen, because the spark burns more brightly; (2) and (3) contain no oxygen.

(*b*) Test for the presence of starch in the (1) green leaves, (2) variegated leaves, (3) petals, taken from the three flasks.

Result. Starch will be present in the green leaves, in the green parts of the variegated leaves, but not in the petals.

These experiments show that chlorophyll is necessary for making starch.

In Book II we saw that salt can be recovered from a salt solution by evaporation. The mineral salts which are taken up to the leaves in water, stay behind in the cells, after much of the water has been given off as vapour through the stomata. Experiments prove that these mineral salts too, form an essential part of plant food.

8. To show the use of mineral salts to the plant

Apparatus. Two jars, soil, distilled water.

Nearly fill two large jars with distilled water. In one put a handful of soil. Make for each a cardboard lid with a hole in the middle, and fix an oak or bean seedling so that its roots dip into the water. Stand the jars in a sunny window and observe their progress.

Result. After a week or two the seedling without soil looks sickly and then dies; the other develops and makes healthy growth.

QUESTIONS ON CHAPTER 4

1. What raw materials do plants need for manufacturing their food? Whence are these obtained?
2. What conditions are necessary to enable plants to manufacture their food?
3. What chemical changes are made in the preparation of plant food?
4. What is chlorophyll? Describe an experiment to show that it is necessary for the formation of starch.
5. Describe an experiment to show that light is needed during the manufacture of plant food.
6. Draw the apparatus and describe the experiment to show that plants obtain carbon from the air for the manufacture of starch.
7. Describe an experiment to show that plants give out oxygen when manufacturing food.
8. Why is no starch found in flower petals and mushrooms?
9. What is the meaning of photosynthesis?

10. What use do plants make of the mineral salts taken in by the roots?

11. What other foods besides starch do plants manufacture? What use do plants make of the food they prepare? Where is the surplus stored?

12. What use do plants make of water absorbed by the roots? What happens to the surplus not required for food?

CHAPTER 5

RAW MATERIALS FROM THE SOIL

THE raw materials which plants get from the soil are chemicals called *salts*. We have seen that these salts are soluble in water and that they are taken up through the root and stem to the leaves, where much of the water passes out of the plant and the salts are left behind. Then they combine chemically with other substances to form plant food.

Carbon from the air, with hydrogen from the water, combine to form sugar and starch in the green leaves, and with the mineral salts as well, they form proteins, while oxygen from the carbon dioxide is returned to the atmosphere.

It is obvious that many plants contain a large amount of water. If this is removed, the solid substance which remains must be formed of carbon and mineral salts. First it is necessary to find out what percentage of water a healthy plant contains, and then proceed to analyse the solid structure.

Experiments

1. To find the amount of water a plant contains

Apparatus. A green plant, a vessel with a lid.

(*a*) First carefully weigh the plant and record the weight. Next place it in an oven or heat it in a vessel

with a lid over a Bunsen flame to drive out the water. After cooling, weigh the plant again. This is the *dry* weight.

Result. The difference in the weight before and after the plant was dried is the weight of water it contained.

Many plants contain a high percentage of water. It may be a surprise to know that some plants with fresh leaves consist of 75 per cent of water, and some water plants contain as much as 98 per cent.

(*b*) Having found the dry weight, the dry plant is then burnt. This needs a special apparatus or crucible and much care. The carbon, of which it largely consists, joins the oxygen from the air and goes off as carbon dioxide. Nitrogen, as well as hydrogen, also disappears into the air, while the plant is burning.

After burning, the ashes remain. These are really the mineral salts, though they are somewhat changed by the burning process from what they were in the living plant; but in this state it is possible for scientists to know just what they are.

2. To find the weight of the mineral salts

Apparatus. A porcelain crucible, the dry plant.

Dry and weigh a porcelain crucible. Place in it the dry plant, then heat it thoroughly until the leaves char or flame and are reduced to ashes. Allow to cool, then again weigh the crucible and its contents. From this deduct the weight of the crucible, and the result gives the weight of the ashes.

Result. The weight of the ashes is the weight of the mineral salts.

3. To find weight of carbon, nitrogen and hydrogen

Deduct the weight of the ashes after burning from the dry weight of the plant. The difference is the weight of these elements which disappeared during the burning process.

It has been proved by experiments that most green plants need supplies from the soil of nitrogen, sulphur, calcium, potassium, phosphorus, magnesium, and iron, which are generally absorbed in the form of salts.

Soils

A fertile soil will contain most of the elements mentioned and, in addition, the decaying remains of dead plants and animals. This organic matter in soils is known as *humus*.

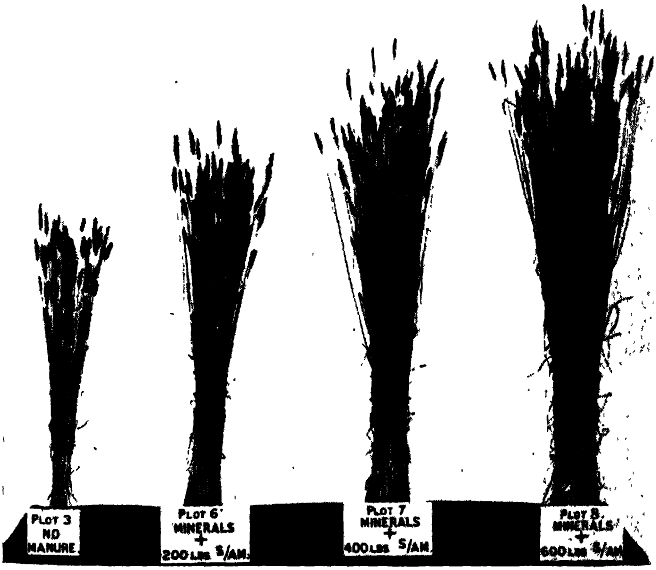
There are various kinds of soils. Some soils consist chiefly of *clay*, others of *sand* or *chalk* while others are composed of mixtures of these. Different soils, therefore, contain various mineral salts and just as animals vary in their diet, so plants require different foods. Scientists have discovered what are the chief salts for the various cultivated plants and which soils will be best for certain crops. If the soil has not enough of the particular salt, the necessary chemical can be mixed with it. Chemicals supplied to the soil in this way are known as *artificial manures* (Fig. 18).

Artificial Manures and Water Cultures

These chemical salts can be bought at any chemist's shop, and their effect on plants can be shown by experiments in the science room. They are soluble in water, so

can be dissolved in the water in which the plants can be grown. The solutions made by them are called *water cultures*.

Each chemical can be dissolved in a separate jar of water, or, by adding the chemicals together in various ways, a number of different solutions or water cultures can be made. Then, in order to decide which foods are best for certain plants, the plants are arranged with their roots dipping into the water containing certain known salts.



Rothamsted Experimental Station

Fig. 18. Results of growing wheat in unmanured soil and in soil treated with various artificial manures.

Water culture experiments

First prepare a complete food solution which contains all the following chemicals. Then make a series from which one salt is in turn omitted.

(*A*) To make a complete solution

(1) Water one pint; (2) Saltpetre (potassium nitrate) enough to be heaped on a sixpence; (3) Epsom salts (magnesium sulphate) about half the amount of saltpetre; (4) Powdered plaster of Paris or gypsum (calcium sulphate) the same quantity as Epsom salts; (5) Acid sodium phosphate the same quantity as of Epsom salts.

(*B*) To make a solution without nitrogen

Prepare this water culture as for the complete solution *A*, but omit saltpetre. This should be replaced by potassium chloride, or, if this cannot be obtained, use acid potassium phosphate instead of sodium salt.

(*C*) To make a solution without potash

Prepare the water culture as for the complete solution *A*, but replace potassium nitrate by sodium nitrate.

(*D*) To make a solution without calcium

Prepare the culture as for the complete solution *A*, but omitting gypsum.

(*E*) To make a solution without phosphate

Prepare as for the complete solution *A*, but omitting acid sodium phosphate.

All these chemical salts are inorganic substances, and when plants are grown in these water cultures they can get only inorganic food materials. The carbon food can be obtained only from the air.

Now set up plants in various water cultures.

Apparatus. Twelve jars with cardboard lids, twelve small iron nails, brown paper, cotton wool, twelve broad bean or oak seedlings.

Make up two quantities of each of the above five water cultures and pour them into ten jars. Fill the two remaining jars with water only. In each of the others place a small rusty nail, because iron is a necessary part of plant food.

In each jar fix a seedling through a hole made in the cardboard lid, so that the seed itself is just below, and use the cotton wool to hold it in position. Tie brown paper around the jars to keep the roots in darkness. Mark the letters of the cultures on the jars and stand them all in a sunny window.

Look at them every day and make a diary of the changes you observe. Head the pages in your book: *A*, *B*, *C*, *D*, *E*, *F*.

How Plants digest their Food

Starch is a solid substance, so it has to be changed again before the plant can use it for nutrition. When we eat solid food it has to be broken down or *digested*; so that it may get into our blood and be carried away to all parts of our bodies.

All higher animals digest their food much as we do, but plant food is simpler than ours, and therefore the

digestive process of plants is simpler too. The starch food which they manufacture is in a solid form and must be digested so that the plant can use it. Plants have not digestive organs and glands as animals have, though in some parts there are juices, or *ferments* as they are called, which have a chemical reaction on the food. These ferments or *enzymes* change starch to sugar and to other simpler substances. In plants, the ferment which changes starch to sugar is called *diastase*.

All higher animals have enzymes for digesting food. When the solid food is changed by the enzyme it can then be used by the plant or animal to keep it alive and to make new living material.

QUESTIONS ON CHAPTER 5

1. What are salts? How are salts formed in Nature? How can they be made in the science room?

2. How could you find the amount of water which a plant contains?

3. What is meant by "dry weight" of a plant? How could you find it?

4. How could you find the weight of mineral salts which a plant contains?

5. Describe how you could find the weight of carbon, hydrogen and nitrogen which a plant contains.

6. Give the names of the chief elements which plants require from the soil for healthy growth.

7. What are the chief kinds of soils? Why are different crops grown on different soils?

8. What do you understand by (*a*) humus, (*b*) artificial manures?

9. What are water cultures? What chemicals are required to make a complete solution?

10. How could you show that each chemical food is required by the plant?

11. Describe how plants digest the food they make.

12. Write what you know about diastase and other enzymes.

CHAPTER 6

TRANSPIRATION

Plants give out Water

Many plants consist of a high percentage of water and most of them absorb a large quantity of water from the soil. Much is needed to bring the mineral salts up to the leaves, and also in the manufacture of food in these factories. But the roots absorb much more water than the leaves require for making food, so large quantities are given off, through the stomata, as water vapour. This process is known as *transpiration* (Fig. 19).

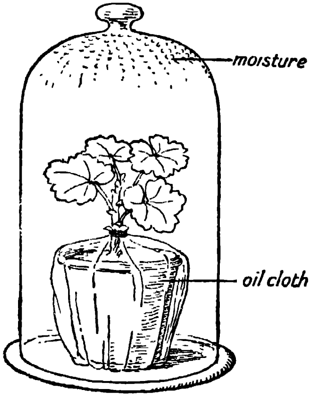


Fig. 19. Plants give off moisture

This upward stream of water with its load of mineral salts passes through pipe-like cells or *wood vessels*, which are grouped together to form conducting tissue called *xylem*, and spread out to the veins and cells of the leaf blade.

Experiments

1. To find the xylem or water paths

Leave a groundsel or other small herbaceous plant in water coloured with red ink, for two or three hours.

Cut thin transverse sections from the stem and examine them on the screen from the microprojector. The water paths will be indicated by the cells containing the red liquid.

2. To show the paths of the transpiration current to the leaves

Cut any leaves with broad thin blades and long stalks, for example, violet, and place them in water coloured with red ink, so that their cut ends dip into the liquid.

Result. The red liquid soon appears in their veins.

Scientists now know that not only is there a constant stream of water from the roots to the leaves, conveying food materials to the factories, but there is also a system of canals through which the manufactured food is distributed to living cells throughout the plant. The distribution of the food is also carried out by means of water.

It is necessary for plants, especially those growing in dry soils, to retain a certain amount of water or they will die. For this reason they regulate the amount they give out according to the supply taken from the soil. Those growing in dry soils obtain little and consequently give out little; others in moist places absorb much and transpire freely. Plants growing in damp places adapt themselves by producing large leaves with numerous stomata to transpire the water quickly; those growing in dry soils have very small leaves, often covered with hairs, and have only few stomata. In fact some plants growing in very dry places instead of leaves may have spines or no leaves at all, in order to reduce the amount of water given out. Such plants usually have green stems. Why?

3. To show that plants give out water vapour

Apparatus. Plant in a pot, oil-cloth, bell-jar.

Place a plant in a pot under a bell-jar having first covered over the pot and soil with oil-cloth.

Result. In a short time the vapour given out by the plant will condense and form small drops of water on the jar (Fig. 19).

4. To show which part of the leaf gives out water

Apparatus. A few large leaves, three jars, 'Vaseline'.

Under jar No. 1 place three leaves which have their under surface smeared with vaseline. Under jar No. 2 place three leaves with the upper surface smeared with vaseline. Under jar No. 3 place three leaves with no vaseline on them.

Result. Water will condense in jars Nos. 2 and 3. In jar No. 1 it will not.

This experiment shows that water is given out through the under surface of the leaves, which has numerous small holes or stomata. When the leaf is smeared with 'Vaseline' the holes are blocked and the water cannot get out.

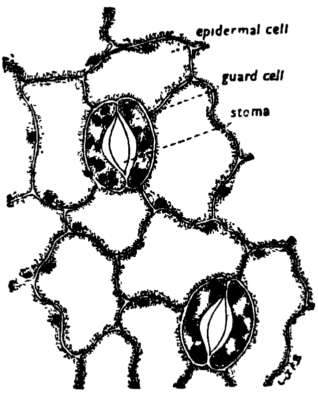


Fig. 20. Surface view of stomata

STOMATA

Observations

(1) Remove a piece of the under skin or epidermis of a leaf and examine it on the screen from a microprojector.

(2) Examine the under surface of a leaf from sections prepared on slides shown on the screen (Fig. 20).

It will be seen that just near the under epidermis of the leaf are numerous air spaces. Stomata lead from these through the epidermis. The water to be discharged by the plant collects in the cells around the air spaces. Then it evaporates and passes through the stomata out of the leaf.

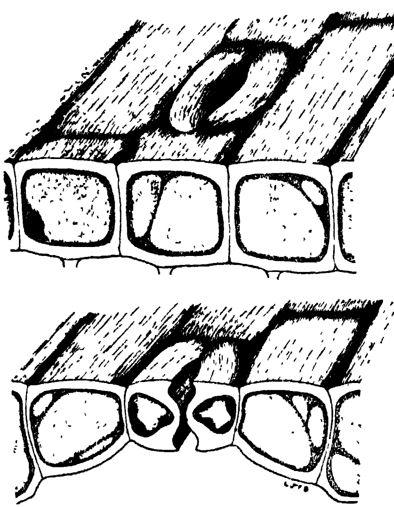


Fig. 21. Transverse section of the epidermis of a leaf showing a stoma (above), and passing through a stoma (below)

If you examine a stoma highly magnified, you will see surrounding it, two curious little cells shaped like beans (Fig. 21). These are called *guard cells*, because they are capable of swelling and shrinking to change the size of the opening and so guard or regulate the amount of water passing out. During a dry period, when the roots have difficulty in absorbing moisture, the guard cells shrink and move close together to close the stomata, so as to prevent too much water passing out. On the other hand, when the water supply is plentiful, the guard cells swell and open the stomata to allow the excess amount to pass through (Fig. 22).

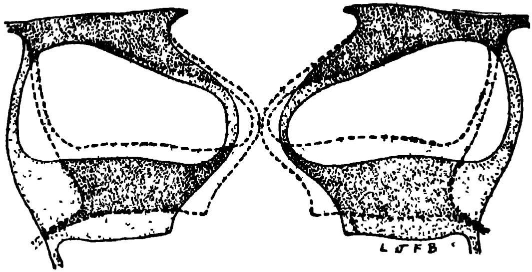


Fig. 22. Diagram of the movement of guard cells. Dark shading, open ; light shading, closed

From the movement of the guard cells it is obvious that transpiration varies according to weather and soil conditions. More water is given out when the air is dry and warm than when it is moist and cool. Transpiration is also greater on sunny days than when the sky is cloudy ; for in bright sunlight food is manufactured quickly and water brings the raw materials to the factories and then passes out through the wide open stomata.

QUESTIONS ON CHAPTER 6

1. Describe the passage of the water from the roots to the leaves.

2. How could you find the xylem tissue in a herbaceous stem?

3. Why do plants need water in dry weather?

4. Describe a stoma and guard cells.

5. How could you show that water passes out of the plant from the under surface of the leaf?

6. Describe how transpiration is increased and decreased in plants.

7. Plants regulate the amount of water given out by the quantity they can receive. Explain how they do this.

8. Compare the leaves of plants growing in wet and dry soils.

CHAPTER 7

RESERVE FOOD IN PLANTS

ON sunny days and in favourable conditions, plants manufacture more food than they require for their immediate use. The amount they do not use then is stored for the times when conditions are not favourable for them to satisfy their present wants, or such times as when buds and flowers are opening and extra food is required for these quickly growing parts. But the same kind of food is not made and reserved by all plants. It varies according to the raw materials absorbed and the kind of food required by the particular plant. Consequently some plants have food stored in the form of starch; some have sugar; some have oil; while others have proteins in their store houses.

Plants also have various organs in which to store their food. Some plants store it in their roots; others in their stems or leaves; and we have seen that all plants store food in their seeds, for this is a natural provision of the parent for its young. Beet, for example, stores sugar in its roots; the potato has starch in its underground stems; the flax has oil in its seeds; and the garden pea stores proteins in its seeds.

By simple tests it is easy to find out what are the reserve foods in some plants.

PLANT FOODS

1. To test for starch in potatoes

Apparatus. A potato, iodine solution.

(*a*) Touch a slice of potato with iodine solution.

Result. Almost immediately it turns purplish black, thus showing that the cells contain starch.

(*b*) Examine a section of potato on the screen from the microprojector.

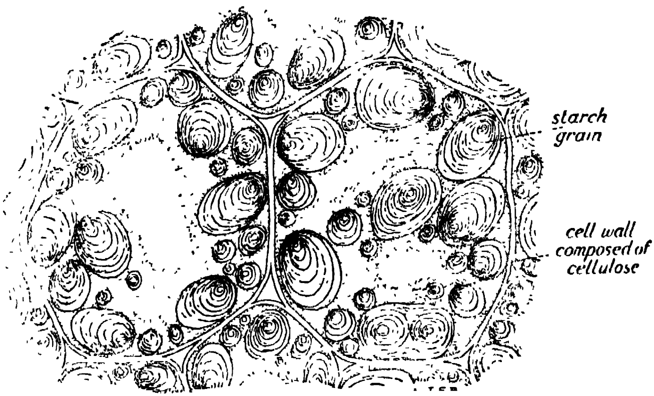


Fig. 23. Starch grains in cells of a potato tuber

Result. Starch grains, appearing like mussel shells, may be seen in the cells (Fig. 23).

2. To test for sugar

Apparatus. Test-tube, a little honey, Fehlings solution.

Fehlings solution is a chemical preparation which turns red in the presence of certain kinds of sugar. It is

usually bought ready for use. It is contained in two separate bottles labelled *A* and *B*. When required for detecting sugar equal quantities of solution *A* and solution *B* and water are used.

Dissolve a little honey in water in a test-tube. Add a few drops of Fehlings solution and watch the colour change to blue. Warm it over a Bunsen flame.

Result. The colour changes and an orange red precipitate forms at the bottom of the tube. This result indicates the presence of sugar.

3. To detect sugar in an onion

Apparatus. An onion, Fehlings solution, test-tube.

Pulp a slice of onion and place it in a test-tube with a little water. Add Fehlings solution and warm it.

Result. A red precipitate forms at the bottom of the tube.

4. To test for cane sugar

Apparatus. A few crystals of cane sugar, Fehlings solution, dilute hydrochloric acid, sodium carbonate.

(*a*) Repeat the above test using cane sugar. No precipitate is formed.

(*b*) Take another quantity of cane sugar solution and add a drop of dilute hydrochloric acid. Then boil it in a Bunsen flame for several minutes. When it is cool add a little sodium carbonate until the effervescence stops. Then add Fehlings solution and boil again.

Result. A precipitate now forms because the cane sugar has been changed to a simpler form of sugar by the acid.

5. To detect the presence of oil in plant tissue

Apparatus. Olive oil, sunflower seeds, castor oil seeds, flax seeds.

(*a*) Place a drop of olive oil on a piece of paper. Hold it up to the light. The oil outlines a light greasy mark on the paper.

(*b*) To detect oil in (1) sunflower seeds, (2) castor oil seeds, (3) flax seeds.

Crush one of each of the seeds (1), (2), (3) between two pieces of paper. Hold the paper up to the light.

Result. A similar light oily mark appears on the paper.

6. To show that oil will not dissolve in water

Apparatus. Olive oil, water.

(*a*) Add a drop of olive oil to half a test-tube of water. Shake it thoroughly to break up the oil.

Result. A cloudy mixture is formed. When allowed to stand the oil floats on the surface of the water.

(*b*) Cut sections of castor oil seeds and float them on water.

Result. Globules of oil appear similar to those in the above experiment.

7. To detect the presence of proteins in seeds

Apparatus. Peas, Millon's reagent, test-tube.

Millon's reagent is a chemical preparation used for detecting the presence of proteins. Crush a pea and mix it with a little water in a test-tube. Add a drop of Millon's reagent.

Result. The mixture turns cloudy white. Heat it in a Bunsen flame. It changes to a pale brick red colour. This colour indicates the presence of a protein.

When starch, protein, oil and other foods reserved in their storage cells are drawn upon by the plant, they must be changed or digested, before they can be used to form plant substance. This change is brought about by ferments or enzymes, of which there are various kinds, but each acts on one particular food substance. We have seen that starch in seeds is changed into sugar by diastase; similarly, fat is broken up by the enzyme *lipase*, and proteins are split up by an enzyme called *pepsin*.

QUESTIONS ON CHAPTER 7

1. Where do plants store food which they need for future use?
2. What are the chief kinds of food made by plants?
3. Describe and draw a section of potato which has been treated with iodine as you see on the screen from a microprojector.
4. How could you detect the presence of sugar in honey and in an onion?
5. What chemicals would you use for finding sugar in (*a*) cane sugar, and (*b*) beetroot?
6. How could you detect the presence of oil in (*a*) castor oil seeds, (*b*) sunflower seeds, (*c*) flax seeds?
7. Describe an experiment for proving the presence of proteins in peas and beans.
8. How are reserve foods changed, so that they can be used by the plant to build up new living substance?

CHAPTER 8

RESPIRATION IN PLANTS

From the moment a living creature starts life it begins to respire, and as soon as it stops respiring it dies. According to this statement one might conclude that respiring maintains life.

We have seen that, in order to live, every creature must also perform a certain amount of work, as it acts or moves. In fact, work is involved in all movements, whether they are brought about by chemical changes, whether they are caused by the functions of internal organs, or by the use of limbs.

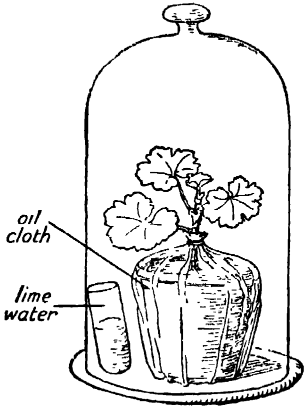


Fig. 24. To demonstrate respiration in plants. The lime water gradually turns milky

Since movements are begun and maintained by different forces, there are evidently various forms of energy. For example, there is electric energy, heat energy, and, as we have seen, chemical energy. It is interesting to find out how living things get their energy which enables them to perform all their activities.

Food consists chiefly of carbon and possesses stored within itself potential energy and this requires oxygen to set it free. During respiration the necessary oxygen

is taken in from the air and combines with the carbon in such substances as starch and sugar in the body of the creature. This goes off as carbon dioxide and liberates the heat energy which is required by the organs and tissues of the body.

Food therefore requires oxygen in order to supply the necessary energy for the living organism, and this is obtained by the process of respiration. In all the more highly developed animals there are special respiratory organs. Man and the higher vertebrates have lungs, fishes have gills, and some lower animals respire through their skin. In plant life it is in living cells, especially in the leaves, that oxygen is consumed, the carbon dioxide formed and energy liberated.

All living plants and animals respire (Fig. 24).

Experiments

1. To show that germinating seeds absorb oxygen

Apparatus. Jar, bent tube, peas, potassium hydrate.

In a jar containing germinating peas, place a small test-tube containing potassium hydrate, a substance

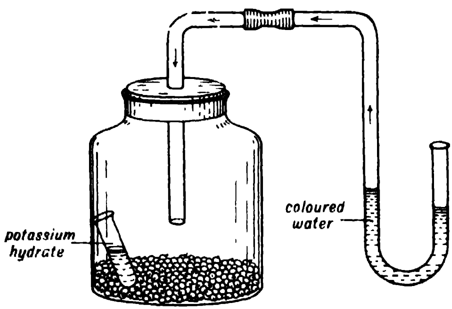


Fig. 25. Germinating seeds respire and absorb oxygen

which absorbs carbon dioxide. Through a tightly fitting cork pass a bent tube containing coloured water as in the diagram (Fig. 25). As the peas give out carbon dioxide in respiration it is absorbed by the potassium hydrate, and the water rises in the arm connected with the tube. This takes the place of the oxygen which was in the air in the jar, and which has been used by the peas during respiration.

2. To show that germinating seeds lose weight

Apparatus. A jar, peas and beans.

Weigh twelve peas or beans and place them in a jar under conditions favourable for germination. When the seeds have shrunk because the reserve food is being used for growth, weigh them again.

Result. There is a slight loss in weight.

3. To show that heat is liberated during germination

Apparatus. A jar containing germinating seeds. A thermometer.

Place a thermometer in the jar containing germinating seeds (Fig. 26).

Result. The thermometer shows a rise in temperature.

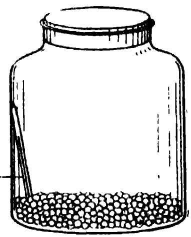


Fig. 26. Heat is liberated during respiration

These experiments show that when seeds germinate, the same things happen as when a candle burns, namely: (*a*) oxygen is used; (*b*) carbon dioxide is given out; (*c*) there is a loss in weight; (*d*) heat is produced.

We have again to consider where the carbon dioxide

comes from. It is clear that oxygen is taken in from the air and unites with the carbon of the plant. At first it enters into the living plant substance which contains carbon. Then some of the carbon breaks away from the living substance and at once combines with the oxygen. Then together they escape into the air as carbon dioxide. Hence some of the living plant substance is used up during respiration, and this explains the loss in weight.

During respiration, therefore, the same things happen as when carbon burns. Respiration, therefore, is slow combustion, and, during the process, heat is produced and carbon joins the oxygen and goes into the air.

You will remember that, in the food-manufacturing process in the leaves, the plant takes in carbon dioxide and gives out oxygen. This is just the reverse of what happens during respiration. There is, moreover, this further difference between the two processes. The food manufacturing business is carried on only during the day when it is light; but respiration goes on at all times. Living creatures never stop respiring, whether active or at rest.

QUESTIONS ON CHAPTER 8

1. From what source do living things derive their energy?
2. Give the names of three kinds of energy.
3. What happens when a candle burns?
4. Explain how respiration is a slow burning process.
5. In what way may food be compared with a piece of coal?
6. Describe an experiment to show that plants respire.

7. Describe an experiment to show that heat is liberated during respiration.

8. Explain why animals lose weight during respiration.

9. Contrast the process of food-manufacturing with that of respiration.

10. What same things happen when seeds germinate as when a candle burns?

CHAPTER 9

RESPONSE OF PLANTS TO LIGHT, WATER AND GRAVITY

LIGHT is an essential factor in the life of every green plant. In plant life there is a constant struggle for existence, and in the crowded plant communities many have to adapt themselves in various ways in order to obtain air, food and light to keep alive.

PLANTS RESPOND TO LIGHT

The effects of light on plants may be seen in those growing in the open fields, and in others struggling in the shaded woodlands, as well as in those placed in light, shady and dark places for observation.

Usually plants begin their life in the dark, for most seeds are sown in the soil to germinate. The effect of light on germinating seeds has already been observed by simple experiments described in Books I and II.

Experiments

1. To compare seeds grown in dark and in light

Apparatus. Two boxes containing soil and mustard or cress seeds.

Sow mustard or cress seeds in soil in two boxes. Place one in a dark room and the other in a light window. At the end of a week or ten days compare the seedlings.

Result. Those grown in the dark are tall, pale and lanky; those grown in the light are green and healthy. The seedlings grown in the dark are pale in colour, so evidently light is needed to produce chlorophyll and thus turn them green.

2. To extract chlorophyll from green leaves

Apparatus. Beaker, green leaves, ethyl alcohol.

Place a leaf of a cabbage, or any other green leaves, in a beaker partly filled with water. Boil the water over a Bunsen flame to kill the cells which contain the chlorophyll. Take out the leaf and dip it in another beaker containing ethyl alcohol which dissolves the chlorophyll.

Result. Chlorophyll solution is obtained.

Tests (*a*) Hold the beaker containing the solution for the light to shine through. The colour appears green.

(*b*) Hold it against a black background. The solution reflects a red light.

3. To show that light is necessary for making chlorophyll

Apparatus. A green potted plant.

Stand a green growing plant in a dark room for a few days.

Result. The leaves have a sickly yellow colour.

This proves that light is necessary to form chlorophyll. This fact is made use of in agriculture, especially in the cultivation of celery and potatoes. Soil is drawn around the stems of celery and over the tubers of potatoes to prevent the light from turning them green.

4. To show that leaves turn towards the light

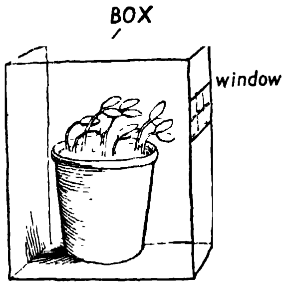


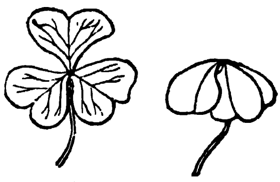
Fig. 27. Shoots turn towards the light

Cut a narrow slit in the side of a cardboard box and place it over a growing geranium. After a few days remove it (Fig. 27).

Result. The stem is bent sideways and the leaf blades are turned towards the light coming through the hole. These experiments show that plants growing in dark or shady places bend their stems and turn their leaves to obtain as much light as possible.

SLEEP MOVEMENTS

Many plants show sleep movements, in that they open their leaves and flowers during the day but close them up at night. The leaves of wood sorrel (Fig. 28) and clover spread themselves to the light but droop or close



From Stork & Renouf's Junior Biology. (John Murray)

Fig. 28. "Open" (day) and "closed" (night) position of leaflets of wood-sorrel

(After Detmer)

Fig. 29. The inflorescence of rough hawkbit. Left, at night; right, during the day

up at night, as a protection from cold and from loss of water by transpiration.

The crocus, scarlet pimpernel, hawkbit and other flowers open and display their petals, to attract insects, in the sunlight, but close when the sky is dull and cloudy (Fig. 29).

5. To induce sleep movements in plants

At noon, cover over a clover plant and scarlet pimpernel. with a large box to exclude the light. After a few hours remove the box.

Result. Notice that the clover has closed its leaves and the pimpernel has closed its petals.

Plants respond to Water

Water also is a necessary factor in the life and growth of every plant. It is required by a plant when starting its life, as the seed cannot germinate without it. Then the mineral salts cannot be absorbed unless they are dissolved in it, and water is needed as an ingredient in the manufacture of plant food.

Experiments

6. To show that water is needed for the germination of seeds

Experiments described in Books I and II show that seeds must have water to make them germinate.

7. To show that roots turn towards water

Apparatus. Wooden box, wire gauze, sawdust, pea seedlings.

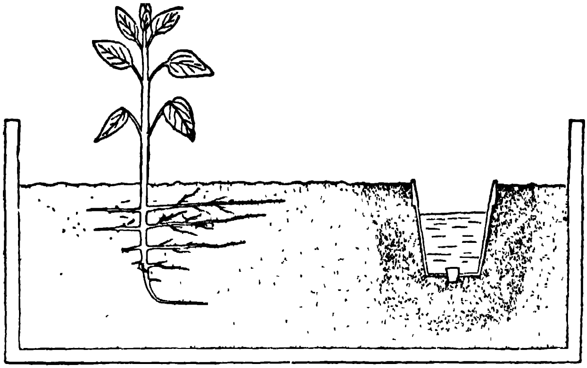


Fig. 30. Roots turn and grow towards a water supply

Fix a piece of wire gauze in the box to form a partition. Fill one side with damp and the other with dry sawdust. Plant pea or bean seedlings in the dry section and observe their behaviour.

Result. After a time the seedlings turn their roots towards the damp sawdust (Fig. 30).

Plants respond to Gravity

Generally all plants are fixed in the place where they are growing, and the only movements they make are due to growth or response to light and water. They are held in position by the force known as *gravity*. It is owing to gravity that the moon and stars keep their position; that buildings on the earth stand where they are placed; that rain and falling objects are drawn downwards to the earth; and that people and animals are able to walk on

the earth even though it is spherical in shape. Scientists explain that there seems to be a force at the centre of the earth which draws all objects on and around the earth towards it. Roots grow down in the direction of the force, and stems grow up in the opposite direction.

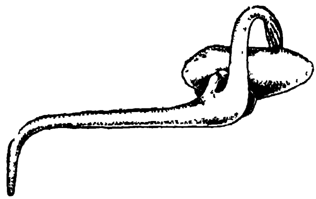


Fig. 31. Roots turn and grow towards the centre of gravity

If a seedling is placed horizontally, it is found that the root grows downwards and the stem upwards (Fig. 31).

Experiment

8. To show the influence of gravity on plants

Fix a pea seedling horizontally on cardboard and place it in a jar containing a little wet sawdust. Stand the jar in a dark cupboard.

Result. After a few days the tip of the root will turn downwards and the stem upwards.

QUESTIONS ON CHAPTER 9

1. Compare germinating seeds grown (*a*) in a light window, (*b*) in a dark cupboard.

2. Describe how chlorophyll may be extracted from green leaves.

3. How could you show that light is necessary for making chlorophyll?

4. What effect has light on the growth of the stem of a plant?

5. What is meant by sleep movements in plants?

6. Why do plants turn their leaves towards the light?

7. Name six plants which show sleep movements.

8. Describe an experiment to show that plants turn their roots towards water.

9. What are the chief uses that plants make of water?

10. Explain what is meant by gravity.

11. What influence has gravity on (*a*) the roots, (*b*) the stems of plants?

12. Describe an experiment to show the influence of gravity on the roots of plants.

CHAPTER 10

PLANT FAMILIES

THERE are such myriads of living creatures that it would be impossible to study them without some sort of scheme of classification.

Some plants and animals differ considerably from others; a pine tree is not in the least like a primrose, nor is a cat like a worm. On the other hand there are many plants and animals which resemble each other very closely. A bee is similar in form and habits to a wasp; a plum resembles a cherry; and a mushroom is in appearance very like a toadstool. Animals and plants which differ only slightly, as these do, are closely related to each other and have descended from the same far-off ancestors. Naturally these form family groups.

Consequently plants (and animals) have been arranged and classified according to their form and structure in all stages of their life-histories. Some plants bear flowers and form seeds; others, such as mushrooms, mosses and ferns, do not have flowers. Plant life, therefore, falls into two great divisions: one group includes all plants which do not have flowers and are known as *Cryptogams*; and the other consists of all the plants which do bear flowers and are called *Phanerogams*.

A. The *Cryptogams* are subdivided into other groups:

(*a*) *Horsetails* and *ferns*. These plants have roots,

underground stems and leaves, but no flowers, so they reproduce in a different way from flowering plants.

(*b*) *Mosses* and *liverworts*. These are small green plants with stems and leaves but with no true roots.

(*c*) *Algae*, *toadstools* and *moulds* like the one which grows on the top of jam and on old boots. These have no roots, stems or leaves like other types of plants. They are the simplest forms of plant life and some consist only of strands of cells. *Bacteria*—organisms consisting of one microscopic cell—are sometimes placed in this group.

B. The *Phanerogams*, or flowering plants, are subdivided into two groups :

(*a*) *Gymnosperms*. This group includes all trees which produce cones, for example, pines, larches, yews, cedars and cypresses.

(*b*) *Angiosperms* is the name of the group consisting of all the ordinary flowering plants. These are the highest type of plant life.

Angiosperms are further divided, as we have seen, into (1) *Monocotyledons* and (2) *Dicotyledons*.

All plants belonging to the group of monocotyledons have several characteristics in common. They have one cotyledon only in the embryo of the seed ; they have leaves with veins running parallel to each other ; and usually they have flowers with their parts arranged in threes or multiples of three. Dicotyledons have two cotyledons in the embryo of the seed ; they have leaves with a main vein giving off smaller ones ; and their flowers have their parts arranged in twos, fours or fives, or their multiples.

Further, those plants which closely resemble one

another in structure and habits are arranged in families because they are believed to have descended from common ancestors.

It is often quite easy to see the family likeness in people too. Sisters and brothers have similar features; probably they have the same coloured hair, eyes or other characteristic, and this may be apparent in cousins as well as in aunts and uncles, because it has been inherited from the same grandparents.

Plants of the same kind form a *species*, and similar species grouped together form a *genus*. Often two or more genera closely resemble one another, so that they are put together and form a still bigger group known as a *family*.

The rose family may provide a good example. There is a great variety of flowers in the rose family. There are white, red and other shades of flowers. Some have five petals; others have numerous petals. The fruit of some is a berry; of others a pome or a drupe. Yet all these with varying fruits are members of one great family and each one bears some of the family features, for they are all descendants of one common far-off ancestor. The cherry, plum, peach and apricot are species of the genus *Prunus*; the bramble is a species of the genus *Rubus*; the apple, pear, quince and medlar are species of the genus *Pyrus*; and all are members of the rose family or *Rosaceæ*.

How to Recognize Members of Plant Families

Every plant family has some mark which distinguishes it from all the rest. Each member of the family bears the

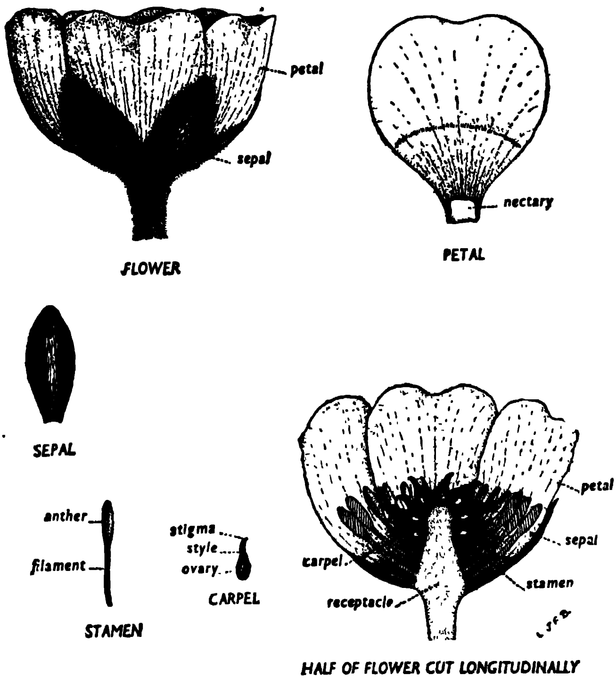


Fig. 32. The buttercup flower

same mark. It is therefore first necessary to learn the distinguishing features of some of the common families. Then you should examine the plants growing in their natural habitats, and collect from them those which you want to observe more closely in the science room. You will need the help of a Flora—a book which gives a description of all the most familiar plants and classifies them into families, genera, species and varieties.

The following is a very general description of a few

important flowering plant families. The letter in brackets indicates whether the family belongs to the dicotyledons or monocotyledons.

1. Ranunculaceæ (D)

This is the family name of the buttercup. All members of this family may be recognized by their sepals and petals which are usually in fives and not joined together, so that they can be taken apart separately. They have an indefinite number of stamens and carpels too. Many of them have their leaves much divided. Perhaps the best-known members of this family are the buttercup, lesser celandine, marsh-marigold and monkshood (Fig. 32).

2. Cruciferæ (D)

This is the name of the wallflower family. Members of this family are recognized because they have flowers with their parts in twos and fours arranged in the form of a

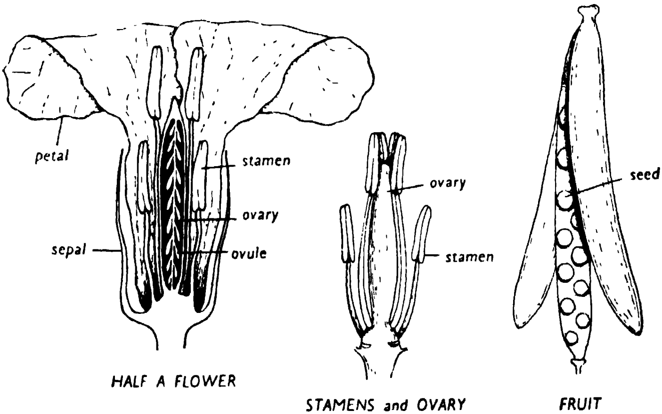


Fig. 33. The wallflower

cross. They also have six stamens, but four are long and two are short, and an ovary with two chambers divided by a partition which bears the ovules. When the fruit is ripe, it splits open and the seeds, attached to the partition, are dispersed (Fig. 33).

3. Leguminosæ (D)

This is the name of the bean family. All members of this family have flowers with parts shaped like those of the sweet pea. They have five sepals and five petals. One large petal is called the *standard*; the two side ones are known as *wings*, and the two small ones are joined to form the *keel*. These flowers have ten stamens. In some, nine are joined together and one is free. In others, all are joined. The ovary is one long chamber, and when the fruit is ripe it is known as a *pod* or *legume*. Many of

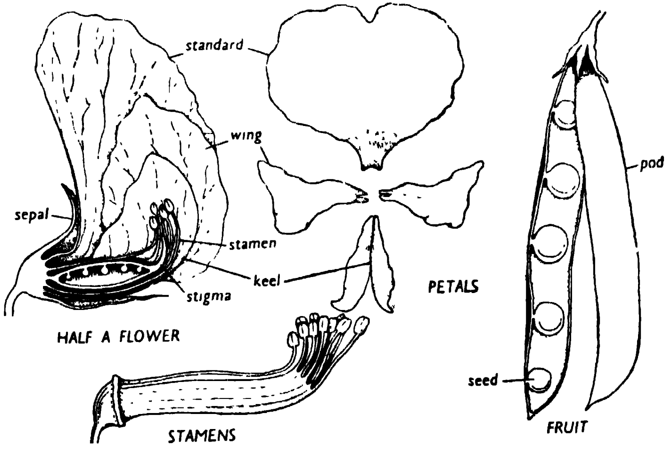


Fig. 34. The pea flower

these plants have slender stems and leaves modified into tendrils, which enable them to climb so as to reach up for light and air. Beans, peas, gorse and vetch belong to this family (Fig. 34).

4. **Labiateæ** (D)

This is the name of the dead-nettle family, and it is so called because all the members have flowers with a curved petal resembling a lower lip. Plants belonging to this family are easily recognized by their square stems, simple opposite leaves and lipped irregular flowers arranged in clusters around the nodes of the stem. The sepals are joined and the labiate, or lip-shaped, corolla is formed from five petals. They may have five stamens, but one is often suppressed ; the ovary is divided into four parts. Most of these plants secrete volatile oil to attract or ward off insects. Lavender, wild thyme, mint, dead-nettle and ground-ivy are well-known members of this family (Fig. 35).

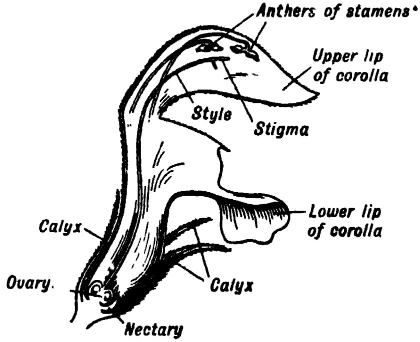


Fig. 35. Section through a white dead-nettle flower

5. **Rosaceæ** (D)

Everybody knows the distinguishing features of the rose family. The stems of these plants often bear prickles, and some have compound leaves with stipules at the base.

A. H. Bastin

Fig. 36. Flower of dog-rose being pollinated

The flowers of the wild rose have five united sepals, five free petals, numerous free stamens and carpels (Fig. 36).

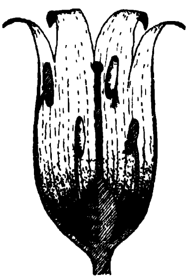
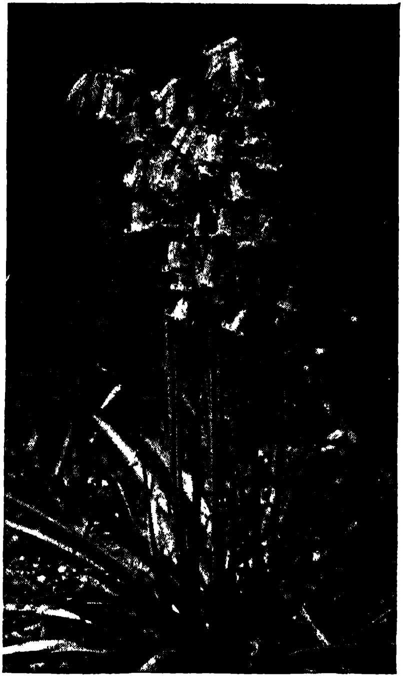


Fig. 37. Section through bluebell flower

6. Liliaceæ (M)

All members of the lily family may be identified by their long narrow leaves with parallel veins, and by their bell-shaped flowers which have their parts in threes and sixes. They have a superior ovary divided into three chambers and most of the



A. H. Bastin

Fig. 38. The bluebell

plants are herbs with underground stems. The bluebell, lily-of-the-valley, Solomon's seal, tulip and the star of Bethlehem are common members of this family (Figs. 37 and 38).

QUESTIONS ON CHAPTER 10

1. What are the names of the two great divisions of plants?

2. Give the names of three smaller groups into which non-flowering plants have been divided.

3. Give the names of the two groups into which flowering plants are sub-divided.

4. How are plants further classified? What decided scientists to classify them in this way?

5. Why are plants grouped into families?

6. What are the chief features of the rose family?

7. How could you recognize a member of the lily family?

8. What are the characteristic marks of the wallflower family?

9. Define the following terms: species, genus, family.

CHAPTER 11

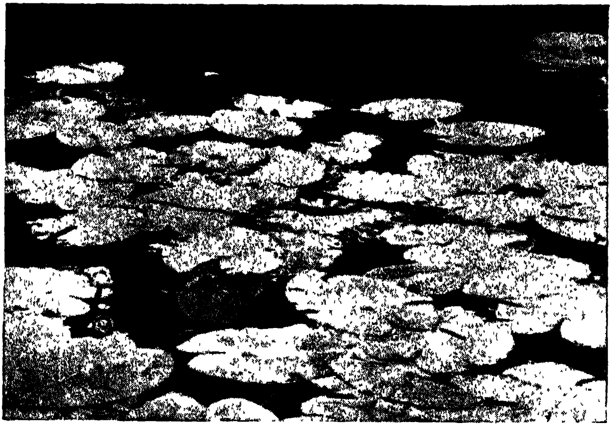
THE PLANT AND ITS SURROUNDINGS

PLANTS living in different parts of the world have to adapt themselves to the particular type of soil, climate and other conditions in which they are growing. Among plants there is a constant struggle for existence. Many are crowded so closely together that only the strongest are able to obtain food, light and air, and to survive. These successful ones are the best able to adapt themselves to changes in the weather and soil conditions. The weakest die.

Plants adapt themselves in various ways. Some modify their roots, stems and leaves for climbing, others growing in moist situations develop leaves capable of discharging large quantities of water, while those in dry sandy soils have small hairy leaves to prevent too much water evaporating from them. Every kind of plant prefers its own particular soil from which to obtain the food it likes best. Some prefer soils formed chiefly of clay, others thrive best on limestone, loam or sandy soils. Most plants flourish best in a mixture of these soils containing humus.

PLANT ASSOCIATIONS

As a result of these adaptations, plants which thrive best in the same conditions live together in societies. Many grow together in certain localities although be-



Henry Irving

Fig. 39. The yellow water-lily

longing to widely different families, because they all like the same kind of soil, the same amount of moisture, and same degree of light and shade. These conditions are most suitable for them. Such groups of plants are called *plant associations.*

Streams and ponds. These have very characteristic plant associations. The plants are modified for living in water. Those which grow in streams have special air cells in their stems and have long ribbon-like leaves, the best form to resist the movement of the running water, for example, water lobelia. Plants growing in ponds have air spaces in their large floating leaves to make them light, and have their stomata on the upper surface to give out water freely. The water-lily (Fig. 39) and duckweed are common pond plants.

Marshes and bogs. Marshes and bogs are soils which

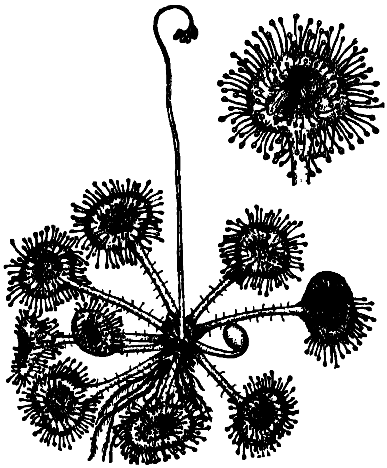


Fig. 40. The sundew showing tentacles on the leaves with which insects are trapped and digested

are water-logged, so that the plants living in these localities have their lower parts buried in the wet mud and are adapted to an aquatic life, while their upper parts, exposed to the air, resemble land plants. Usually the members of these societies have long narrow leaves as the iris, rushes, horsetails, lady's smock, water-mint and water forget-me-not. In some bogs may be found the sundew and butterwort. These are very interesting plants because they feed on insects which they catch with their leaves and then absorb the juices into their tissues (Figs. 40 and 41).

Meadow associations. These are composed chiefly of grasses. There are many kinds of grasses, but perhaps the most common are the perennial rye grass, the meadow

fescue, Timothy grass, meadow foxtail and quaking grass. Growing among the grasses are the buttercup, daisy, white clover, speedwell, knapweed, cowslip, and other associates.

Henry Irving

Fig. 41. The butterwort

Hedgerows. Hedgerows usually provide a very interesting study of plant societies. Besides the hedge itself, which may be formed of hawthorn, gorse, privet, hazel, holly or blackthorn, or a mixture of these, often the bank on which it grows produces a large variety of smaller plants, different ones growing where the soil is moist or dry, and in the light or shade. At the top of the hedge bank, the soil is dry and the light feeble. On this part, therefore, are plants with long stems, as hedge-mustard, dead-nettles, campion and grasses so that they may reach high to more light; while climbing plants, such as honeysuckle, bramble, black bryony, hop, clematis and wild rose, scramble up and over the hedge, and outstretch all (Fig. 42) the others.

Lower down the bank where the light is brighter and the soil contains more moisture, there is a greater variety of small herbaceous plants. Near the bottom may be found such plants as lady's smock, cuckoo-pint, celandine and kingcup, and in the water of the ditch may

Henry Irving

Fig. 42. A hawthorn hedge covered with black bryony and bramble

grow various water plants, such as brooklime, watercress and duckweed.

Moorlands. These have a very definite type of vegetation. A moor is an elevated tract of country consisting generally of dark peaty soil. On these bleak stretches of high land, the plants are much exposed to the strong cold winds and rains, and to the heat of the sun (Fig. 43). Ling or heather is the dominant moorland plant, but bell-heather, bilberry and cotton-grass are usually found in its society.

Flatters & Garnett, Ltd

Fig. 43. Cotton-grass growing in a bog—on a moor

Heaths. Heaths are stretches of open lands at lower levels and produce other types of plant societies. Pines, birches, alders, willows and bog myrtles are characteristic of the heath lands, and with them grow ling, bell-heather, gorse, bracken. grasses, bedstraw, milkwort and other small plants. Sometimes the butterwort and sundew are found in these societies in the more boggy places. Most moorland plants are woody and all are hardy to endure severe conditions. Their stems are stunted, their leaves are small and protected with very thick cuticles against the heat and cold and excess loss of water (Fig. 44).

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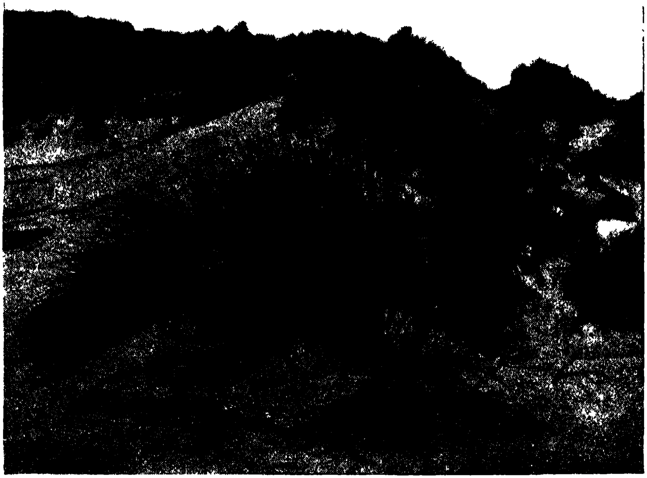
Fig. 44. Upland heath

Sand-dunes. These produce another type of plant society. Sand-dunes are heaps of dry loose sand formed near the seashore and support only scanty vegetation. The seaward slopes are almost barren though sometimes a few coarse grasses and sedges manage to exist there. At the top of the dunes sedge, marram grass, lyme grass and sea couch grass bind the loose drifting sand with their long, thin, stems running underground. On the landward slopes where the soil is firmer, there are more varieties which may include rest-harrow, wild thyme, silver weed,



W. B Crump

Fig. 45. A sand-dune

sea campion and stonecrop. All sand-dune plants have short tough stems and small prickly leaves, so they can regulate the amount of water passing out (Fig. 45).

Woodlands. In the British Isles there are several types of wood associations. These vary with altitude, soil and weather conditions. Generally the tall trees form the wood because they become *dominant* and restrict the variety and number of other plants growing near them. The smaller bushes, shrubs and climbing plants form the *undergrowth*, and the short, herbaceous plants nearest to the ground form the *carpet* (Fig. 46).

The different types of woods, therefore, vary with their situations and conditions. On the high lands are the

W. B. Crump

Fig. 46. Oak wood in summer

pine woods. Pines are hardy trees and can live in poor, dry soils and cold, exposed positions. Their roots grow long to reach more moisture, their barks are dry and

rugged and their leaves, arranged in pairs, are long and narrow and usually known as needles.

Birches also grow on high ground and are native trees of Britain. The silver birch, conspicuous by its slender trunk with smooth and silver bark, spreads its long thin branches bearing leafy twigs, and from its grace and elegance is called the " Lady of the Woods ".

In many woods the tall trees grow together or spread wide their branches and turn their leaves to the light, and make a canopy so dense that only a few shade-enduring plants are able to live beneath them.

In more open spaces various shrubs often grow among the birches. These may include the sloe, hawthorn, guelder rose as well as the climbing plants honeysuckle, wild rose, hop and bramble. Among the small herbaceous plants are often found the bluebell, wood-anèmone, garlic, dog's mercury, wood-sorrel and wood-spurge, many of which have bulbs or rhizomes to protect them from very dry and very cold seasons.

At lower levels there are other types of woodlands depending on the different kinds of soils. Usually in Britain beech woods are produced on the chalk or calcareous soils. Beeches provide some of the most beautiful scenes of the woodlands. Their trunks are massive and covered with an olive-grey smooth bark. From them spring the wide spreading branches bearing a multitude of long oval leaves with pointed tips which cast a shade so dark that they prevent most other plants from growing beneath them. When young the leaves look green and silky, later they become smooth and shining, and, on the approach of autumn, they change their colours to yellow, gold, purple and warm russet brown. Through-

out the season, the leaves spread themselves to the sun and allow very little light to pass between them.

Near the edge of the woods bluebells grow in plenty, but elsewhere, scattered only here and there, are the woodrush, sanicle and wood-sorrel, while in the deep rich humus, only such plants as the bird's-nest orchis and fungi are able to survive. Among the clearings and where the light breaks through the canopy may be found the traveller's joy, columbine, dog's mercury, ragwort, agrimony, enchanter's nightshade and foxglove, with their associates.

In contrast to the beech woods are the ash woods, though they, too, grow on lime and sandy soils. The ash is an open tree and the canopy casts no deep shade even when the leaves are at their largest. This tree has a smooth and massive trunk; but as it grows older, its green grey bark splits open and makes light deep fissures.

In the autumn, after the leaf-fall, the dark green, almost black buds become conspicuous, but they are well protected by scale leaves, until late spring, when they burst open and grow into compound leaves with thin pointed leaflets. Even when fully open they allow much light to pass between them, so that many other plants may grow beneath them.

Consequently ash woods are rich in undergrowth and have many shrubs and bushes, as well as a great variety of small flowering plants.

Oak trees grow on the lower hills and usually where the soil is dry and sandy, though some prefer the damper soils. With the drier conditions are the dry oak woods and their associates. Gorse, heather and bracken fill the open spaces; larch, holly and hazel trees mingle

with the oaks, and the bluebell, yellow dead-nettle and foxglove are the most numerous of the smaller plants.

At lower levels, where the sand is mixed with clay, the soil is more retentive, and damp oak woods are common. These admit many shrubs and bushes, especially the hazel and hawthorn, while the violet, primrose, bugle, viper's bugloss, wood-sorrel, creeping Jenny, and pink campion flourish among the ground flora.

On the lowland plains, the richer soils of clay and loam support a greater variety of plants. Here competition is keen among the larger trees, and the ash, oak, elm, poplar, horse-chestnut, sycamore, hornbeam and lime all strive to be dominant, while smaller shrubs of elder, spindle, hazel, crab-apple, hawthorn and wayfaring tree with many climbers form a dense assembly of undergrowth. The ground flora including silver weed, pink campion, cranesbill, herb robert, speedwell, dead-nettle, buttercup, stitchwort and grasses make a thick and beautiful carpet.

At yet lower levels, the wide alluvial plains produce another type of vegetation. These low flat lands stretch along the beds of streams, and are overlaid with flood deposits. Usually this new alluvial soil is very fertile, though it is often very wet and subject to river floods. Willows and alders generally form the dominant trees, while cowslips, oxlips, kingcups, and celandines flourish among the tall coarse grasses of the riverside meadows and marshlands.

How to study plant associations

If possible, obtain or make an outline map of the area to be observed. First find the area on a physical map of

the district, or on one which shows the geology and physical features. From this you may learn the types of rocks and the soils formed from them, as well as the altitudes above sea-level.

Next make a general survey of the district, noting the plains, hill slopes and high lands covered with their contrasting vegetation. On the blank map indicate, by using appropriate colours or signs, the different types of vegetation in their relative positions as they occur on the various soils. These types or plant associations may include some of the following: woodlands, scrub-land, meadow, moorland, marsh, water, cornfields, hedgerows, etc.

Having thus obtained a general impression of the vegetation, select a small area to observe in greater detail. Using a measuring tape or rope divide the area into smaller rectangles, and draw this to scale in your notebook. First observe the tall trees or plants which appear to be most numerous. These are the dominant plants. If not too numerous, count them, and indicate their position on the map. Next observe those which are less numerous and consequently sub-dominant. Count those too, and show their relative distribution on the map. The area may include part of a wood. Similarly observe the undergrowth, and record the names and numbers of each species. Lastly, examine the small herbaceous plants forming the ground flora. These you may be able to count and classify so that you can indicate their names and numbers on your map.

When the practical work is finished, the map should be a picture record of your observations. It should also bear (1) a scale showing the size of the area observed,

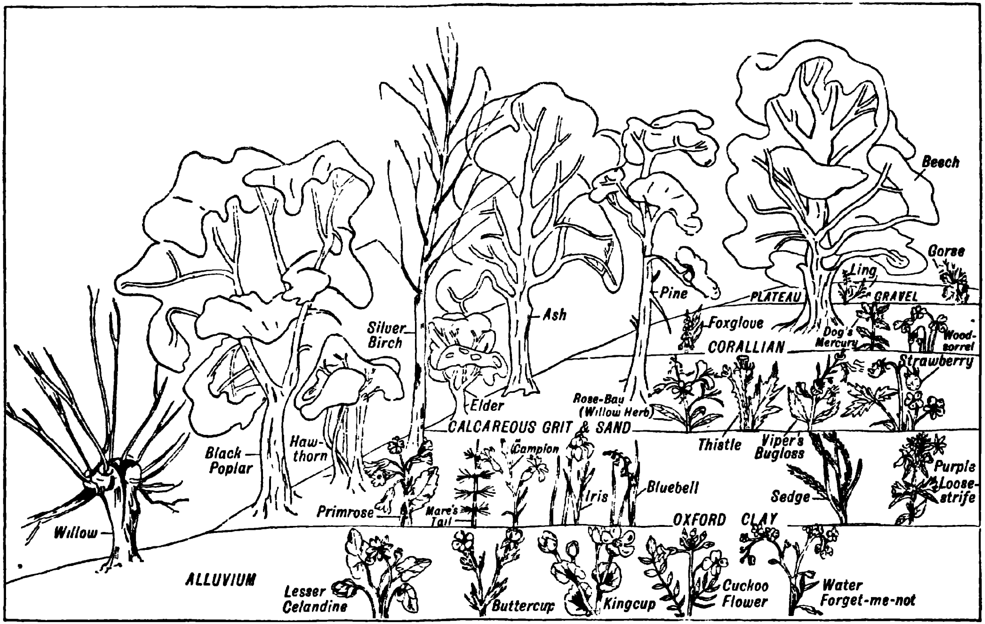


Fig. 47. Zones of vegetation on a hill slope near Oxford

(2) a key of the signs or colours, (3) a summary of the plant members of the society.

Further observations should then be made of the structure and habits of the plants generally in order to discover what features are common to all members of the society.

Often it will be found that all the plants living together find that particular type of soil and the other natural conditions provided in that situation most suitable for them, or it may be that some plants have been transported there and have adapted themselves to their new environment. All plants growing on a moorland, for example, have long penetrating roots, stunted woody stems, small hairy leaves with thick cuticles, and very small flowers.

Fig. 47 illustrates the results of observations of zones of vegetation growing on a hill slope near Oxford. The types of plant associations are produced from the different kinds of soils formed from the underlying rocks, and also by the variation in altitude on the slope of the hill.

The hill rises from the alluvial plain of the Thames Valley to a height of 478 feet. It stands on a foundation of limestone and is composed of a bed of Oxford clay overlaid by a layer of calcareous grit and sand and one of coral rag, and is capped by a drift deposit of plateau gravel left by melting ice. The diagram shows the dominant plants with their associates growing on the various types of soils. The plateau gravel at the top is almost barren.

QUESTIONS ON CHAPTER 11

1. What do you understand by plant societies?

2. What are the general characteristics of the plants growing in streams and ponds?

3. Name six plants that you would expect to find growing on a marsh. What features have they in common?

4. Describe the vegetation of a meadow.

5. What is a moorland? Describe the kinds of plants growing there.

6. Describe a hedgerow which you know.

7. Describe the vegetation of a sand-dune.

8. Describe a beech wood.

9. What is a mixed wood? Describe one which you have visited.

10. What kinds of plants grow on low clay plains?

11. What plants would you expect to find on an alluvial river plain?

12. Where would you expect to find the following plants : primrose, hedge-mustard, willow, kingcup, beech, traveller's joy, honeysuckle, gorse, stonecrop, Scots pine, cotton-grass and bluebell?

CHAPTER 12

CONE-BEARING PLANTS

GYMNOSPERMS form a group of plants which bear flowers and seeds, *but the seeds are not protected in an ovary like those of Angiosperms.* The most important examples are the conifers which bear their seeds in cones. Most cone-bearing plants are large and evergreen trees. Among the best known in this country are the pine, fir, larch, yew, spruce, cypress, juniper and monkey puzzle. This group also includes some of the oldest and some of the largest trees that exist at the present time. The redwood, or giant tree of California, is one of them. Some of these trees grow very big, and in one case a hole was cut through the trunk large enough for a car to pass through.

THE SCOTS PINE

The Scots pine is one of the British cone-bearing trees. It is an evergreen and grows to be a large tree with a round, straight stem, covered with a rugged scaly bark. The branches are formed in whorls and produce long, narrow, green leaves which are known as needles and which grow in pairs (Fig. 48).

The flowers of the Scots pine are *cones.* There are two kinds (*a*) the male cones, (*b*) the female cones.

The male cones appear about the middle of May when they are produced in clusters at the end of small branches.

A cone is really a spike, bearing overlapping scale-leaves. Attached to each scale is a stamen filled with pollen. Each pollen grain contains a male cell and has two little outgrowths containing air. These make it very light and easily carried by the wind.

The female flowers grow as little brownish pink cones; but after fertilization they become hard and woody. These cones produce two kinds of scale-leaves. The larger ones bear two ovules which develop into seeds.

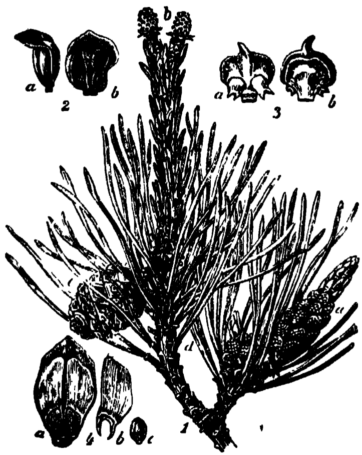


Fig. 48. The Scots pine

1, branch with male (*a*) and female (*b*, *c*) cones; 2, two views of a stamen; 3, scales bearing ovules; 4, scale with two seeds (*a*), wing (*b*), seed (*c*)

In May or June the scales of the female cone spread out and the pollen is blown in by the wind. Then they close again and are sealed tightly. During the first year the pollen appears to be dormant; but the next year its male germ joins the egg and the two nuclei form a new cell, or zygote. At once it begins to divide and make more cells and soon the embryo of the seed is formed.

Then the cone increases in size and turns green in colour; but it is not until the third year that it reaches maturity and opens its scales which are now dry, brown and woody, for the fully formed, winged seeds to escape.

Each seed consists of a radicle, plumule, and several cotyledons, as well as a supply of food.

QUESTIONS ON CHAPTER 12

1. Give the names of six cone-bearing trees which grow in the British Isles.
2. Describe a Scots pine or any other conifer you know.
3. Describe the male cone of the Scots pine.
4. Describe the female cone of the Scots pine.
5. What happens after a female cone is pollinated?
6. Describe a seed of the Scots pine.

CHAPTER 13

FERNS

FERNS belong to a group of plants which are more simple in structure than Angiosperms and Gymnosperms, because, although they have a root, stem and leaves, they do not bear flowers or form seeds. These plants are usually found in shady places and moist soils, and grow abundantly in woods and on hill sides.

Among the best-known ferns are the common bracken, which grows on heaths and in open woods, the male fern, which grows in damp shady places, and the hart's-tongue fern, which grows on dry banks and walls.

Closely related to ferns are horsetails. These form a very ancient family of plants which are fast dying out; but the struggling survivors grow in dense colonies in bogs or wet clay soils. Horsetails have roots, stems and leaves, but no flowers. Their stems are hollow and curiously jointed, and their leaves are round and pointed and also have many joints.

In tropical countries some ferns grow as high as tall trees; but most of the British ferns grow as herbaceous plants with leaves three or four feet in length, growing from a thick short rhizome. The leaves are compound and much branched, and, when growing, are called *fronds*. Each leaf takes two years to develop. At first it is coiled round and round the tip so that it looks like a bishop's crozier, and gradually uncoils itself as it grows (Fig. 49).

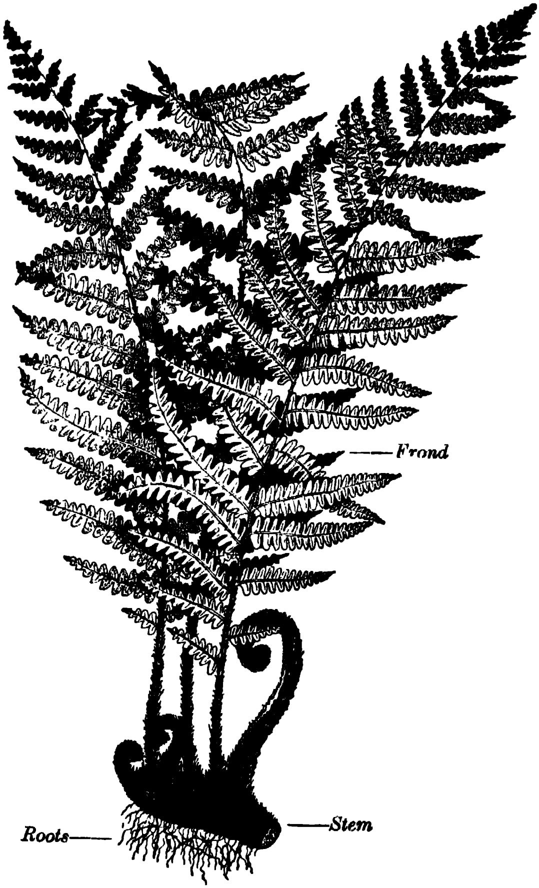


Fig. 49. A fern

Reproduction of ferns

Although ferns have no flowers and do not form seeds they are able to reproduce themselves in two other ways :

(*a*) By buds. On the old leaves of many ferns little buds appear. These grow bigger and develop roots as the leaves decay, and finally they fix themselves in the soil, produce new leaves and thus become independent plants.

(*b*) By spores. New fern plants are also developed from *spores*. These are single cells and differ from seeds which are formed from two cells, a sperm and an egg. On the under surface of the leaves of many ferns are little brown kidney-shaped structures called *sori* (Fig. 50). If a young sorus is examined through a lens it will be seen to consist of a collection of very small club-shaped bodies, called *sporangia*. These contain special cells, known as *spore mother cells*, which produce the spores (Fig. 51).

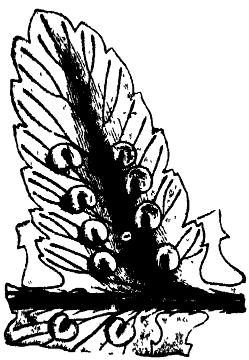
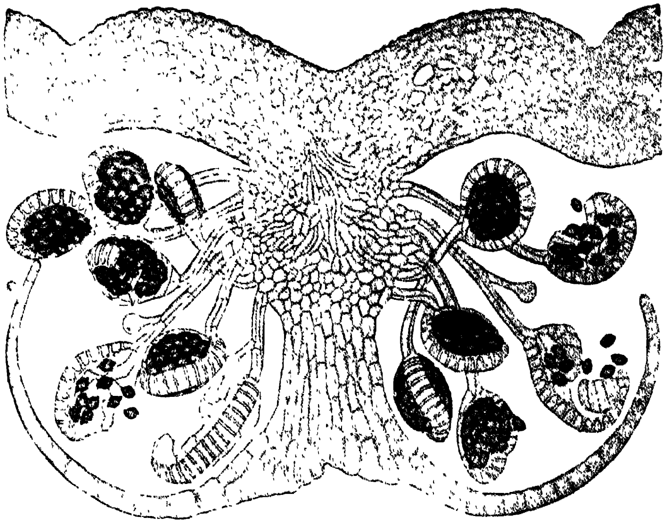


Fig. 50. Part of the under surface of a fern leaf showing the sori

A spore may be examined on the screen from the microprojector. Each one is composed of a single nucleus surrounded by protoplasm and protected by a cell-wall.

When the sporangium is ripe and the weather dry, the spores are set free. If they chance to rest on moist and suitable soil, they germinate, and each one may grow into a little plant shaped like a heart, and about one-third of an inch across, called a *prothallus*.



(*After Kny*)

Fig. 51. Section through the sorus of a fern, showing the sporangia containing spores

This forms a definite stage in the development of the fern. On this little plant are two kinds of structures, one contains *sperms* and the other *egg cells*. A sperm may be compared with the male germ in the pollen grain and an egg cell to the ovum in the ovule in a flowering plant or pine. When free the sperms swim about until they reach an egg. Then one of them joins the egg and the two cells together form a zygote. At once this new cell begins to divide and soon grows into a new fern plant, with roots, rhizome and fronds, resembling the one which produced the spores (Fig. 52).

Ferns, therefore, have two definite stages in their life-history. Development of this kind is called *alternation*

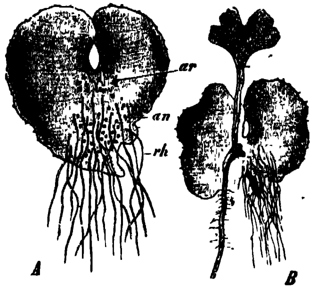


Fig. 52. A fern prothallus. (*A*), viewed from the under-side showing rhizoids (*rh*) by which the prothallus obtains nutrition from the soil, sperm-producing organs (*an*) and egg-producing organs (*ar*); (*B*), a young fern plant growing from the prothallus

of generations, because alternate, instead of succeeding, generations have the same form and resemblance.

QUESTIONS ON CHAPTER 13

1. How do ferns differ in structure from flowering plants?

2. Give the names of the best-known ferns growing in this country. State where they are usually found.

3. Name the two methods by which ferns increase their numbers.

4. Describe the method of reproduction by spores.

5. What is meant by the term alternation of generations?

6. Describe the following: frond, rhizome, sorus, sporangium.

CHAPTER 14

LOWER PLANTS

Liverworts and Mosses

Liverworts and mosses belong to another group of plants, which are even more simple in structure than ferns. These plants usually grow in damp, shady places and some actually grow in fresh water.

Pellia is the name of one of the commonest liverworts. It is a curious little plant and appears as a green, flat, leaf-like structure, called a *thallus*. From its under surface grow long white hairs, called *rhizoids*, which perform the work of roots, in fixing the plant and absorbing raw food materials from the soil.

Fig. 53. A moss plant

The little moss plant is familiar to everybody and, like *Pellia*, it bears no flowers ; but mosses have a very interesting life-history, because they pass through two distinct stages in their development as ferns do (Fig. 53).

ALGÆ

Algae is the name of a class of plants even less developed than mosses, because they have no roots, no stems, no leaves and no flowers, and they live in water. They include seaweeds and a host of fresh-water relatives. Many consist of one cell only, for example, *Pleurococcus* (Fig. 3), and are too small to be studied without a microscope. Some live in the sea, others exist in countless millions, and appear as a green powder, on damp walls. Some are formed of colonies of cells, while others, like the huge seaweeds found stranded on the seashore, are composed of a variety of cells (Fig. 54).

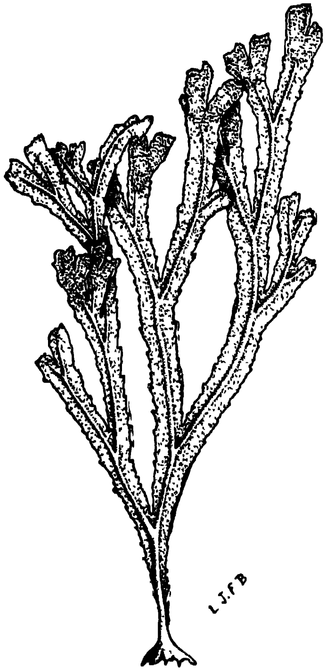


Fig. 54. A seaweed

Observation

If possible obtain water from a stagnant pool and examine a drop on the screen shown from a microprojector. No doubt it will contain many minute plants.

FUNGI

Fungi are a group of plants closely related to Algae, but distinguished from them in that they are never green.

This group contains a great variety of plants. Many are exceedingly minute and some are comparatively large and conspicuous. Mildew, which grows on old books and old clothes, consists of thousands of little plants belonging to this group. Mould too, which appears on cheese, on the top of jam, and on old boots, consists of a dense colony of similar plants (Fig. 55). Mushrooms, toadstools and puffballs are some examples of larger fungi (Fig. 56).

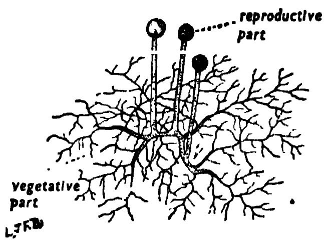


Fig. 55. Pin-mould (× 25)

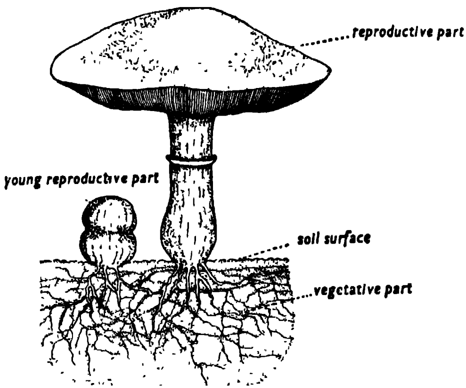


Fig. 56. A mushroom

Fungi have no roots, stems, leaves or flowers, but many of them are made up of tubular threads, called *hyphæ*, instead of ordinary cells. The food of fungi is quite

different from that of flowering plants. Since they are never green, they are unable to manufacture their own food and so they take it from other plants or animals, living or dead.

Some of these plants live on living creatures and are called *parasites*; while others live on non-living tissue and are called *saprophytes*. Here they find food ready prepared for them. To obtain their nutrition, parasitic fungi often penetrate the living cells of the host on which they fix themselves.

Reproduction. Fungi are plants with no flowers and so they reproduce themselves by forming spores instead of seeds. You will remember that a spore is a very specialized cell, capable by itself of giving rise to a new living creature, because it has the power to divide itself again and again into a number of cells.

Some fungi produce numerous spores which are so exceedingly small and light that they are carried about in the air.

Some of these fungi are helpful to man, but others

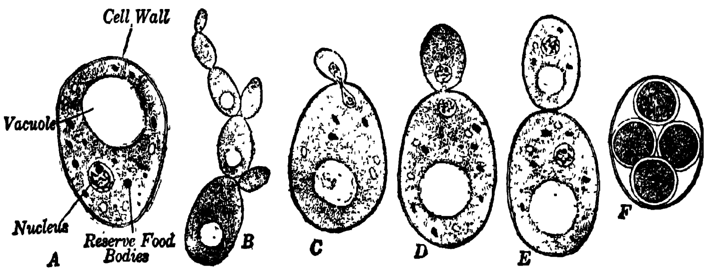


Fig. 57. *A*, a yeast plant; *B*, a yeast plant reproducing by budding; *C*, *D*, *E*, stages in bud formation; *F*, a yeast plant reproducing by means of spores

are harmful and are the cause of disease among plants, animals and human beings. Mushrooms, for example, are even cultivated for use in man's diet, and some fungi are used to produce enzymes capable of causing substances to ferment and change chemically. The fungus yeast is used for this purpose (Fig. 57). This plant has the property of changing sugar into alcohol and so it is used in brewing beer. There are many forms of fungi, however, which must be regarded as pests and therefore be destroyed. They are a nuisance or dangerous to the well-being of man. One kind known as rust attacks the leaves of wheat and fruit trees and causes much damage to these crops.

QUESTIONS ON CHAPTER 14

1. Describe the plant *Pellia* and state to which group it belongs.
2. What kind of plants belong to the class Algae?
3. Give the names of four plants belonging to the group Fungi.
4. How do Fungi differ from Algae?
5. How do Fungi obtain their food?
6. What are (*a*) parasites, (*b*) saprophytes?
7. How does a fungus reproduce itself?
8. Give the name of a fungus which is (*a*) useful, (*b*) harmful to man.

CHAPTER 15

BACTERIA

BACTERIA form a race of the smallest known living things ; some are so small that they are only visible under very powerful microscopes. These extremely minute creatures are closely related to fungi. Some bacteria have, like animals, the power of motion, but animals are composed of cells which have no cell-walls, yet these have walls of cellulose like those of plants. Some scientists, however, regard bacteria as a sort of bridge between the plant and the animal world, and consider them as a third kind of living thing.

Generally these creatures are mentioned as *germs* or *microbes*, and they are found everywhere. They occur in vast numbers in the air, in sea- and fresh-water and in the soil. Many also live as parasites on other living plants and animals, or as saprophytes on non-living matter, while quite a number live on inorganic material.

Many which live as parasites on animals are harmless ; in fact, some of them are very useful to other creatures and to man too. Others, on the contrary, are most harmful and are the cause of infectious diseases, including typhoid fever, anthrax, tuberculosis, diphtheria, measles, mumps and various plagues (Fig. 58).

Bacteria generally consist of single cells of protoplasm inside a cell-wall, and they vary considerably in shape. When seen under a powerful microscope some appear

spherical in shape, others are rod-like, others spirally coiled, and some have the form of commas. Usually they are colourless. Some are able to swim by means of *cilia* or *flagella*, which are outgrowths of the protoplasm.

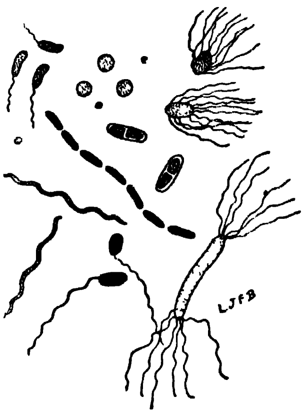


Fig. 58. Types of bacteria

Under favourable conditions, bacteria reproduce themselves with great rapidity. They can do this in two ways. Some simply divide into two daughter cells as amoeba does. To multiply in this way they need plenty of food to make more and more protoplasm. They absorb their food from the liquid in which they live and, if this is plentiful, the cells may divide every twenty minutes, so that in the course of a day or two a single cell of a bacterium may have millions of descendants.

The other method of reproduction is by the formation of spores. When food is scarce these creatures have to adapt themselves to unfavourable conditions. Since they cannot continue to multiply, they become dormant and live in a resting state and so preserve their race, until they are able to increase their numbers again. In the form of spores they can be blown about by air and live for a long time.

Usually a spore is formed inside a cell, and in this state it can withstand the effects of heat and cold; in fact, some spores can even endure boiling for a considerable

time. Bright sunlight, however, is fatal to them, and great heat also will kill them. Certain chemicals known as disinfectants will also check their growth or destroy them.

There are some bacteria which are important to man and to other living things, because they possess the power to produce ferments, or to bring about various chemical changes, so that they are able to convert one substance into another. Nearly all decay of organic matter is caused by bacteria or fungi. They multiply so rapidly that some build themselves up into colonies and, if they are harmful, they produce a disease. Often their bad effects are due to the ferments and chemicals they produce. These are their waste products and are poisonous to the creatures on which they live. These poisons are known as *toxins* and they break down the tissues of the animal or man and collect in the blood of the body.

Some bacteria can chemically change milk. They convert the sugar it contains into lactic acid and this makes the milk turn sour. Others change alcohol into acetic acid in the manufacture of vinegar.

There are also races of bacteria living in the soil. In fact the fertility of the soil depends upon their presence, because it is by them that plants get their nitrogen prepared for them. They first bring about the decay of plant and animal matter. From this is produced ammonia and nitric acid, which dissolves mineral substances in the soil so forming ammonium salts and nitrates, which are important food materials for plants.

There are some bacteria also which inhabit the food canal of the healthy human body and, by the action of their ferments, help in digesting food.

How Germs are Spread

When a person is suffering from an infectious disease such as fever or measles, a large number of bacteria live on the tissues of the nose, mouth and throat. When the sufferer coughs or sneezes, many of these germs are discharged into the air around. If another person is near and breathes the same air, he will naturally inhale the bacteria also. There the germs may find favourable conditions for growth, and in this way the disease is passed on.

If, on the other hand, the germs are not inhaled, they may form spores and then rest among the particles of dust. There they wait until they are disturbed and then they may be inhaled by someone in whom they can develop.

In a crowded room the air may contain large numbers of bacteria, and where there is dust there is danger of many lurking spores.

Since prevention of illness is better than cure, rooms should be well ventilated and as much sunlight let into our houses as possible. The human body and clothing should be kept clean by washing, and houses as free from dust as possible.

Generally, however, a healthy body is defended by Nature from attacks by bacteria. In the blood are red and white corpuscles and the latter kill and absorb bacteria in much the same way that amoeba moves and absorbs its food. When germs enter the blood, the white corpuscles at once set up a strong line of defence ; but if they are outnumbered by the invaders, the poisons of the latter cause sickness. Then there is a further demand

on Nature's resources. The body is enabled to form *antitoxins* which render the toxins of the bacteria harmless. In this way the body is able to recover from the disease, and, what is more wonderful, the blood sometimes goes on making antitoxins afterwards and so makes the body immune to further attacks by that particular germ.

With this knowledge, scientists are now able to produce antitoxins. They also obtain certain bacteria which they kill and inject into people to make them immune to the disease. Doctors *innoculate* people against typhoid fever by injecting dead typhoid bacteria ; and vaccinate against smallpox by injecting bacteria of cowpox, closely related but harmless germs.

Growth of Bacteria

Certain forms of bacteria can be cultivated and propagated for useful purposes. A few simple experiments may help us to understand how this is done by scientists.

Experiments.

To cultivate bacteria

A sterilized culture medium will be required. Agar-agar is generally used. This is a jelly prepared from a seaweed. Beef jelly can also be used.

Apparatus. Eight test-tubes, agar-agar, cotton-wool, milk.

The test-tubes must first be sterilized. Place them in a pan of cold water and bring the water to the boil. Continue to boil them for about twenty minutes and then allow the tubes to cool in the boiled water.

Weigh two ounces of agar and soak it in cold water until it is soft; then remove it to a beaker containing 100 c.c. of warm water. Heat this over the Bunsen flame and boil the mixture for about twenty minutes.

Half fill the test-tubes with the hot agar, plug them with cotton-wool and stand them aside to cool in a slanting position. When the jelly is nearly set it is ready for use. Number each test-tube, and make a record of the experiments.

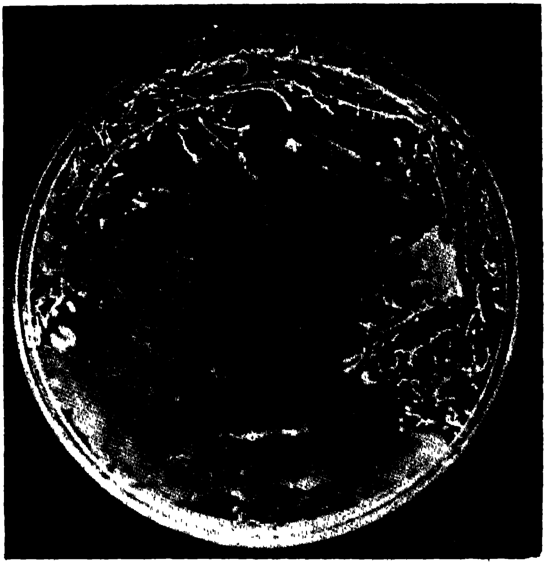


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Fig. 59. Growth of bacteria caused by a house-fly which had been allowed to crawl over a sterile agar plate for three minutes

(1) Leave this tube untouched and label it "control".
(2) Remove the cotton-wool and expose the mixture to the air for ten minutes.
(3) Expose this to the air as No. 2, then add a few drops of disinfectant, *e.g.* Dettol.
(4) Take out the cotton-wool and breathe into it ten times.
(5) Put a fly in for a few seconds.
(6) Add a drop of milk (*a*) fresh.
(7) ,, ,, ,, (*b*) boiled.
(8) Expose this over a dustbin.

Plug each tube again with cotton-wool and place all the tubes in a warm dark cupboard for about a week (Fig. 59).

Observation

(*a*) Look for white or coloured patches on the surface of the jelly. These will be colonies of bacteria.

(*b*) Which has the largest growth?

(*c*) Which has the least?

QUESTIONS ON CHAPTER 15

1. Bacteria are regarded by some scientists as a sort of bridge between the plant and animal world. Explain why.

2. Describe the appearance of bacteria when seen under a powerful microscope.

3. How do microbes obtain their food?

4. How do bacteria reproduce themselves?

5. What conditions are favourable to the growth and reproduction of bacteria?

6. How do some germs protect their race when food is scarce?

7. Where do spores usually rest?

8. Name some germs which are (*a*) useful, (*b*) harmful, to plants and animals.

9. In what way are bacteria useful in the soil?

10. Describe how disease germs may be spread.

11. Describe how disease germs may be checked or destroyed.

12. What happens when germs enter the blood of a healthy person?

13. What are toxins and antitoxins?

14. How can the growth of bacteria be observed in the science room?

15. Describe experiments to show that cleanliness, boiling and disinfectants are important in preventing disease caused by germs.

CHAPTER 16

THE ANIMAL KINGDOM

Classification

Some animals are minute and invisible to the naked eye. They live in the air or in the soil; others of varying sizes live on land or in the sea; but wherever they may exist Nature has equipped them to provide food for themselves and to meet the conditions of their environment.

Consequently it is found that special abilities and characteristics are common to many, and this observation has led zoologists to believe that these have descended from the same common ancestor. They have therefore arranged them in groups according to their kinship.

When studying the various types it will be observed: (*a*) how they are formed, (*b*) how they breathe, (*c*) how they obtain food, (*d*) how they protect themselves against their enemies, (*e*) how they grow and reach maturity and then give rise to other creatures like themselves.

It is also interesting to observe how the various animals use their special abilities, particularly in making their homes, providing for their young, for self-defence, and for the preservation of their race. Some animals have a retiring nature and often live alone or in pairs; others have social instincts and prefer a community life. Bees, wasps, termites, as well as beavers, moles and birds, build their homes on a wonderful plan, while ants live in complex cities (see Chap. 25).

Animals possessing a backbone, such as herrings, frogs, snakes, sparrows and cats, are more closely related to one another than they are to such animals as hydra, worms, snails, crabs, ants and spiders, which do not possess a backbone.

Naturally then, all animals may be divided into two great groups. In one group are all those possessing a backbone; these are known as *Vertebrates*. In the other are all those with no bones, and these are called *Invertebrates*. Each of these groups is further divided into smaller ones, each division consisting of animals resembling one another. The classification begins with the lowest forms which are the unicellular organisms, and then follow in evolutionary sequence, a series of animals arranged in groups according to their stages in development and complexity.

INVERTEBRATES

Name of Group	*Characteristics*	*Members*
(1) **Protozoa.**	Animals composed of only one cell of living material. Many of these are parasites, living on other creatures from which they get their food.	Amoeba.
(2) **Porifera.**	Animals with cells massed together to form a body, with some cells specialized for a particular purpose.	Sponge.
(3) **Coelenterata.**	These animals have two layers of cells forming a body cavity, but they have no separate sense organs or organs for digestion.	Hydra, jelly-fish, sea-anemone.
(4) **Annelida.**	These are animals with long segmented bodies. The body is hollow and they have a definite food canal.	Earthworm, leech, sea worm.

INVERTEBRATES—*Continued*

Name of Group	*Characteristics*	*Members*
(5) **Mollusca.**	These animals have soft, slimy bodies. They have no segments and are often protected with a shell. They have no legs, but move along by a muscular foot.	Snail, slug, oyster, mussel.
(6) **Echinodermata.**	These are animals usually more or less spiny outside and with the parts of the body arranged in rays like a star.	Starfish.
(7) **Arthropoda.**	These animals have a segmented body, protected with a hard horny covering. Their legs are in pairs and much jointed.	Butterfly, ant, bee, crab, spider.

VERTEBRATES

Name of Group	*Characteristics*	*Members*
(1) **Fishes.**	These usually have two pairs of fins corresponding with the fore-limbs and legs of higher vertebrates. They breathe air dissolved in water through special organs called gills.	Goldfish, herring, minnow, codfish.
(2) **Amphibia.**	These animals have two stages in their life-history. (*a*) The young live in water and have gills for breathing. (*b*) The adults can live on land and have lungs for breathing.	Frog, toad, newt.
(3) **Reptiles.**	Reptiles breathe with lungs. Their bodies are covered with scales, and they are cold-blooded.	Snake, lizard, tortoise, crocodile.
(4) **Birds.**	Birds are covered with feathers, have claws at the ends of their toes and lay eggs with shells.	Robin, pigeon, sparrow.

VERTEBRATES—*Continued*

Name of Group	*Characteristics*	*Members*
(5) **Mammals.**	Mammals have their bodies covered with hair. Their young are born alive and are fed with milk by the mother. (The duck-billed platypus and spiny ant-eater of Australia are exceptions. They lay eggs from which the young are hatched.)	Dog, cow, whale, ape, man.

QUESTIONS ON CHAPTER 16

1. Give the names of the two great divisions of animals. How are these groups subdivided?

2. What features did zoologists consider when classifying animals?

3. Name the chief groups of invertebrate animals.

4. Give the names of five groups of vertebrates.

5. Why is an earthworm considered to be more developed than a jelly-fish?

6. Do you consider a snail to be more advanced than an earthworm?

7. What are the main differences between reptiles and amphibians?

8. In what ways do fish differ from all other animals?

9. Why are birds placed in a group by themselves?

10. What features have birds similar to those in reptiles?

11. Why are mammals considered to be the most highly developed animals?

12. Arrange these animals in order of development: spider, wren, hydra, herring, snake, cow, earthworm, snail.

CHAPTER 17

PROTOZOA AND PORIFERA

PROTOZOA

PROTOZOA is the name of the group of the simplest animals. Each consists of a single cell which is really a minute speck of transparent living substance known as protoplasm. They have no limbs for motion, no lungs for breathing, no sense organs for controlling their actions or other organs for digesting their food. Yet each is complete in itself.

Many of these animals live in stagnant pools or in sea-water, and some are protected by a beautiful little shell. Some live in the soil while some are parasites and live and feed within the bodies of insects, worms and other animals ; others produce diseases in man.

These creatures have no limbs, but some of them move about by changing their shape. They project part of themselves and put out false feet (*pseudopodia*). When they feed they surround the morsel with their feet, then absorb and digest it in any part of their body.

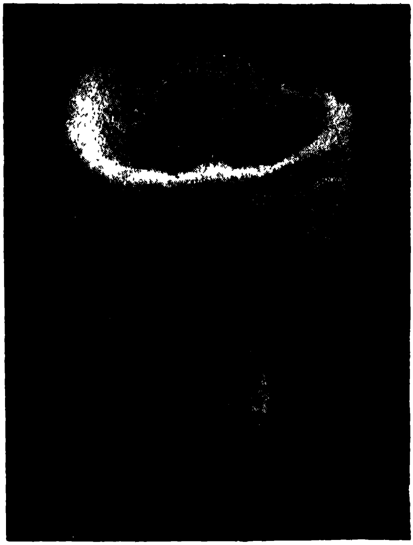
Equally curious is the method by which these animals multiply. As a rule they increase their numbers by each one dividing into two ; then these two divide again and so on. *Amoeba* is a very common member of this group. These tiny animals are abundant in ponds, in soil, in sea-water, and sometimes as parasites.

PORIFERA

Porifera form a group of animals which include sponges. All these, too, are very simple in structure, but they differ from Protozoa in that most of them are formed of a number of cells living in a colony.

A Sponge

In the sponge the cells are clustered together and more specialized than in *Amoeba*, but each has its share in the general well-being of the animal. Some cells obtain food and digest it; some are protective cells; some are used for movement and some for forming new animals (Fig. 60).



F. S Russell

Fig. 60. A turkey-cup sponge

The cells of the living sponge are arranged to form a body cavity surrounded by a jelly-like wall. In some sponges this forms a fibrous skeleton. The bath sponge, as we know it, is really the skeleton of such an animal. The small holes are spaces which lead into the body cavity, and the large holes are outlets from it.

The bath sponge, when alive, was covered with a jelly-like substance and purple skin and lived on the rocks in the Mediterranean Sea.

The Food of a Sponge. Sponges have no mouth or digestive organs ; but the body feeds on particles of food taken from the water. These pass in through the numerous pores, as the water is lashed along fine canals by tiny hair-like lashes called *cilia*. As the water is driven through the sponge it gives to the animal oxygen and food, and carries out with it all the waste matter.

Sponges have no real sense organs, though they have a very low grade of nervous system, but no brain. They have no organs of motion but are fixed, like plants, to the place where they are growing. They can, however, open and close their pores, which is their chief movement.

Reproduction. Sponges increase their numbers by cell division. The cells divide in the same way as *Amoeba* divides, but these cells remain together as a colony and form a sponge. These animals may also be increased vegetatively as one takes cuttings of plants. If one sponge is cut into pieces, each piece soon develops into a new complete colony.

QUESTIONS ON CHAPTER 17

1. Describe an animal belonging to the group Protozoa.

2. Where do Protozoa live and how do they procure their food?

3. Describe how Protozoa increase their numbers.

4. Why are the animals forming the group Porifera considered to be more advanced than the group Protozoa?

5. Why do scientists consider amoeba to be related to a sponge?

6. Describe a living sponge. What part is a bath sponge?

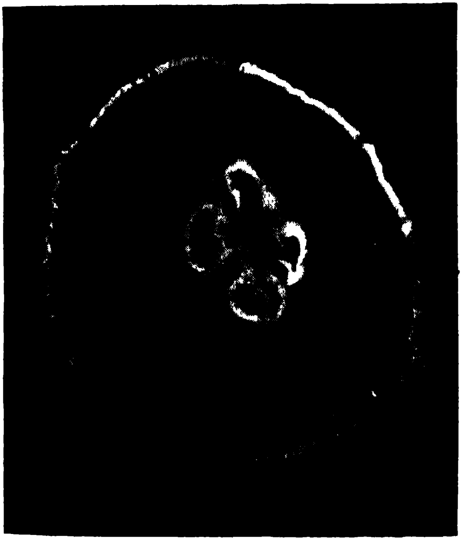
7. How does a sponge obtain its oxygen and food?

8. How do sponges increase their numbers?

CHAPTER 18

COELENTERATA

THE group Coelenterata contains a great variety of animals, and includes hydra, jellyfish and sea-anemone, and also sea firs and corals which live in colonies. All these animals are alike in that they have cells arranged in two layers forming a cavity, which is really a large mouth and stomach. They also possess various sets of cells to do one kind of work, whilst others do other work. Those forming the outer layer are responsible for movement; others are stinging cells for defending the animal and for catching food. The cells of the inner layer are concerned with digesting food, and



D. P. Wilson

Fig. 61. A jellyfish viewed from beneath

there are others forming nerves concerned with the animal's actions. So these animals share out among the various groups of cells the labour necessary for their well-being (Fig. 61).

HYDRA

Hydra inhabits many fresh-water ponds and streams ; it may be found hanging from the leaves of water plants. It is a small animal and appears like a piece of brown or green sewing thread about one-third of an inch in length. In structure it is a hollow tube ; one end is used for attaching itself to an object and the other end is open, forming a mouth. Just below the mouth is a circle of stinging *tentacles* which the animal uses for catching its food, and for swimming in the water, though usually *Hydra* travels by making a series of somersaults on the leaf to which it is attached.

The body wall of this animal is formed of two layers of cells. The outside layer forms the skin and the inside one is used for digesting food (Fig. 62).

The Food of Hydra. The creature feeds chiefly on water-fleas and minute animals which are caught by the tentacles and forced into the mouth. They then pass into the body cavity where they are digested by the juices poured on them from the cells of the stomach. These cells also have cilia which lash the water along, so that the animal absorbs oxygen, retains it for respiration, and gives out waste matter including carbon dioxide to be carried away by the stream.

Reproduction. Hydra is capable of increasing its numbers in two ways. Sometimes little swellings,

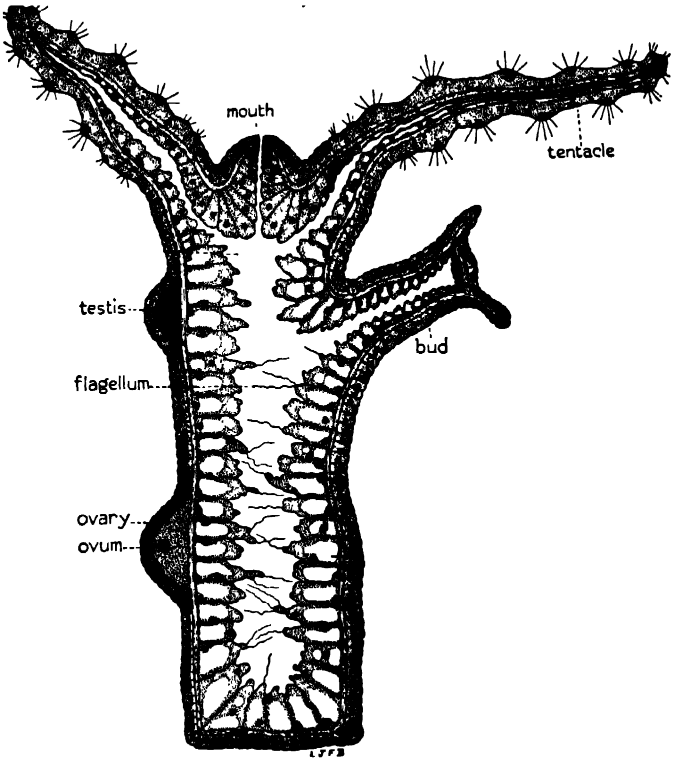


Fig. 62. Section through a hydra

resembling buds on a twig, appear on the sides of the body. Soon tentacles develop, the bud grows quickly, then breaks free from its parent and lives independently. This is *asexual reproduction.*

Hydra can also multiply by the method known as *sexual reproduction.* Small swellings appear on the animal;

one or more near the tentacles, and usually one only lower down. The upper one, the *testis*, contains many male cells or sperms, and the lower one which is the *ovary*, contains an egg cell. After a time the sperms are liberated and swim towards the ovary the outer wall of which splits. Finally one of the sperms reaches the egg cell, and its nucleus unites with that of the egg. The egg is then said to be fertilized, and is capable of dividing to form new cells. This process goes on until it has built up a new animal like its parent.

Sea-Anemones

Sea-anemones are closely related to *Hydra* and resemble it in many ways. They are found in rock pools on the shores of our country. There are many varieties and colours.

In structure, the sea-anemone resembles *Hydra*, though it is much larger. Its body is a tube about three or four inches long and the animal usually attaches itself by one end to the rocks. Around the mouth end are a number of tentacles armed with stinging cells which the creature uses as weapons for procuring its food and for its own defence (Fig. 63).

The sea-anemones resemble *Hydra*, too, in the kind of food they consume and in the way of procuring it.

Reproduction. Sea-anemones increase their numbers by sexual reproduction. They differ from *Hydra*, however, in that the germ cells are formed inside the body cavity, each animal forming one kind only, being thus either a male or female animal. Both animals are alike in appearance, but inside the body cavity the male pro-

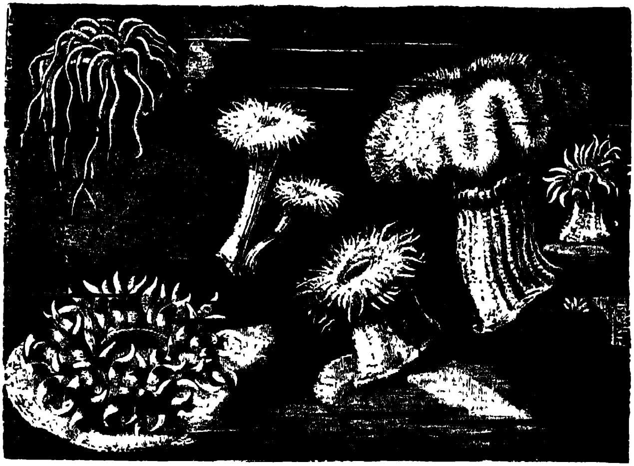


Fig. 63. Sea-anemones

duces sperm cells and the female egg cells. When the sperms are liberated, they enter the mouth of the female and unite with the eggs. Then those develop into larvæ and swim out through the mouth of the parent. Finally they reach a suitable place and attach themselves to a rock where they can develop into full-grown anemones.

QUESTIONS ON CHAPTER 18

1. What features in common have the jellyfish, sea-anemone and *Hydra*?
2. Describe *Hydra* and say where it usually lives.
3. How does *Hydra* obtain its oxygen and food?
4. Describe two ways by which *Hydra* can reproduce itself.

5. Describe a sea-anemone.

6. Describe how the sea-anemone obtains its food.

7. Where do sea-anemones live, and how do they protect themselves from their enemies?

8. How do the sea-anemones give rise to young ones?

CHAPTER 19

ANNELIDS

ANNELIDS form the group which includes the earthworm and all its relations; sandworms, leeches, sea mice, and many kinds of worms are among them.

The Earthworm. All these animals resemble each other in having long, soft, slimy bodies and no limbs,

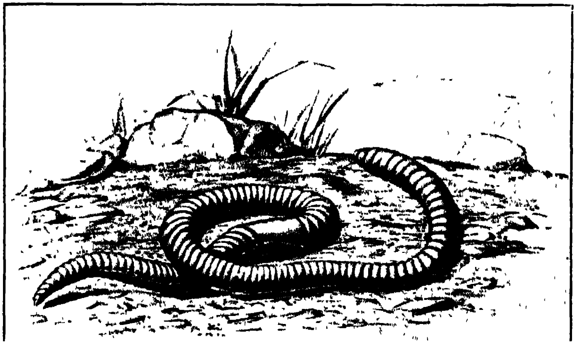


Fig. 64. An earthworm

but they are able to move by means of muscles and stiff hairs or *setæ* which enable them to grip. Their bodies are divided into a chain of rings or segments which are formed of groups of cells joined together; the work for the general well-being of the creature is divided among the groups (Fig. 64).

The Food of the Earthworm. Annelids have a mouth and a digestive tube for receiving and digesting food. The food tube extends the whole length of the body, and the food, which for worms consists of organic matter in the soil, is digested in stages as it passes along the digestive tract.

Worms have no eyes or ears, but they have a definite nervous system which helps them in procuring their food, in defending themselves and in carrying out their other activities. The nerve centre consists of two small swellings, called *ganglia*, which really form a primitive brain. From these which are situated a little above the mouth, a nerve cord runs to the end of the tail and sends out branches around each segment of the body.

Some members of this group have also a system of blood vessels containing red blood. In some annelids these vessels run through the body and are connected with five pairs of little hearts. Since worms have no lungs for breathing, they get their oxygen from the air which passes through the skin and into the blood vessels, and similarly the impure blood sends out carbon dioxide to the air.

Reproduction. The earthworm and other members of this group produce more creatures like themselves by a process similar to that in plants and in *Hydra*. Reproduction is brought about by special male and female cells produced inside the body and *both kinds may develop in the same individual.* But earthworms differ from *Hydra* in that they do not use their own sperms for fertilizing their eggs. They prefer them from another worm, just as some flowers prefer pollen from another flower and are cross-pollinated, so worms are cross-

fertilized. When the eggs are ready for laying, they are carefully protected in a little *cocoon* and hidden in the soil where they may be hatched in safety.

QUESTIONS ON CHAPTER 19

1. Give the names of three relations of the earthworm and the name of the group to which they belong.
2. Why are these animals grouped together?
3. Describe the structure of an earthworm.
4. Describe the nervous system and blood system of any member of this group of animals.
5. How do worms obtain oxygen for respiration?
6. Describe the method of reproduction of the earthworm.

CHAPTER 20

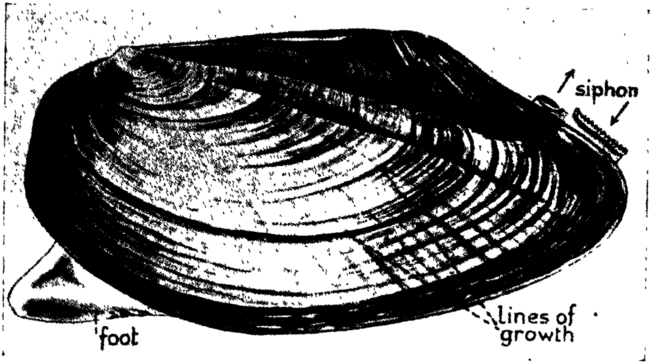
MOLLUSCS

MOLLUSCS are animals with soft slimy bodies, and many of them manufacture a hard shell outside their skin into which they can retreat for protection.

Most of them, including oysters, mussels, whelks, cockles, water-snails, clams, periwinkles, scallops and cuttle-fish, are aquatic animals, and spend all their life in water; but there are some (the garden snail and slugs, for example) which have adapted themselves to live in moist places on land.

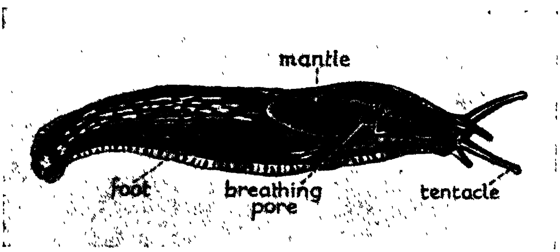
Although some molluscs live in water and others live on land, we find that when we consider their structure and the form of shell they make, this group of animals is really divided into two classes. Each individual of the various kinds makes its shell in its own particular style, just as each individual bird builds its nest in its own particular way. The shell itself is composed of a stony substance, calcium carbonate, and is constantly being made from a fold of skin known as the *mantle* (Fig. 65).

Some molluscs—snails and limpets, for example—make their shells all in one piece, so these animals are called *univalves*; others, including mussels, oysters and cockles, have theirs designed in two pieces hinged together, so they are known as *bivalves*. Some make twisted shells and some kinds appear to have no shell at all. These are the cuttle-fish, squid and octopus. Some marine



Mussel

Snail



Slug

Fig. 65. Types of mollusc

molluscs have no external shell; but have a kind of internal skeleton formed of a horny substance lodged in the mantle. The slug resembles this last class, for on the top of its body there is still a hard substance which scientists say is the remains of a shell and which indicates that slugs had ancestors with shells.

All molluscs have their bodies in one mass and not divided into segments like those of worms. Generally they have no limbs or organs of motion, but move about by means of muscles under their bodies. When the land molluscs come out of their shells their soft bodies spread on the ground and form a wide flat *foot*. Along the under surface—the sole of the foot—are muscles which expand and contract and by their means the animal moves along. These muscular movements make little waves under the foot and may be observed as a snail crawls over a piece of glass.

The snail, like other univalves, has part of its body fixed inside the shell, and around the base of the shell on the body is the mantle. This class of mollusc has a head, bearing well-developed sense organs for seeing, smelling and feeling; but bivalves, including oysters and mussels, are very strange creatures and have no head or sense organs as the others have.

All molluscs, however, have a mouth and food tube where their food is taken in and digested. Many of them have a wonderful tongue covered with numerous tiny teeth, which they use to rasp away leaves and other solid food. If a snail placed on a piece of glass will eat a piece of cabbage, you can watch how, while feeding, it rasps away the leaf.

Bivalves, cuttle-fish, squids and other aquatic molluscs

breathe by means of gills and obtain their oxygen from the water as fish do ; but those which live on land have a special breathing chamber where the air is always kept damp and which corresponds to the lungs of higher animals. During respiration air enters directly into this chamber through a small opening, which in a snail may be seen in its collar on the right side.

Molluscs have a definite nervous system and many have special sense organs. Nerve centres or local brains develop in various parts of the body, and these are joined to each other by nerve strands and also to a ring of nerve substance round the mouth.

A snail has two pairs of *feelers* or *tentacles* and at the end of each of the longer ones is a single eye, which can be turned to see all around. The two smaller tentacles may be used as organs of smell. The snail has a keen sense of smell, for, with these sensitive feelers, it seems able to smell its food as well.

Molluscs also have a heart with two cavities, but instead of blood vessels like those of worms and higher animals, they have special open spaces. These are not clearly seen, because their blood is white or colourless and is forced to these parts by the muscular movements of the heart.

Reproduction. Snails and other molluscs increase their families by laying eggs. These are formed by cross-fertilization, as in the worm. The female snail lays from forty to one hundred eggs and takes great care of them. She protects each one of them with a hard covering before it leaves her body and hides them in the soil. When the young are hatched they grow up in stages, while they are still hidden in the soil.

Nature has provided molluscs with various means of

protecting themselves against their enemies. Many make a shell to protect their soft bodies; some have colourings which blend with their surroundings so that they are not easily seen. Snails and slugs search for their food at night while their enemies, the birds, are asleep. In winter when food is scarce and the weather cold, these animals find a hiding place and *hibernate* there until the spring.

Aquaria

Some of these water animals can easily be kept for a short time in aquaria if they are provided with suitable conditions for keeping them healthy. It is very necessary to keep them supplied with oxygen for breathing as well as with fresh food. For this reason they need water plants in the aquarium with them. The plants use carbon dioxide when making their food, and give out oxygen which the animals require for breathing, while the animals give out carbon dioxide needed by the plants. So by keeping animals and plants together the balance of Nature is maintained.

When providing an aquarium, it is first necessary to obtain a large tank with straight sides. This shape is more suitable than a glass bowl. Then obtain some water plants from a pond and take plenty of the soil or gravel with them. On the bottom of the tank make a layer of pebbles, sand and stones or gravel taken from a pond or stream. Then pour in water also brought, if possible, from the pond or stream where the plants were growing and let it settle. It may be necessary to weight the plants with stones to make them grow and prevent them from floating on the water. A few floating plants are also good

to have in the aquarium. Duckweed is one of the common ones and is found on most ponds and still water (Fig. 66).

It is then very important to stock the aquarium with animals which naturally inhabit the same water, otherwise some will quarrel or prey on others. Sticklebacks, for example, are very quarrelsome little fish, so they are safest in a tank by themselves. Fresh-water snails eat up

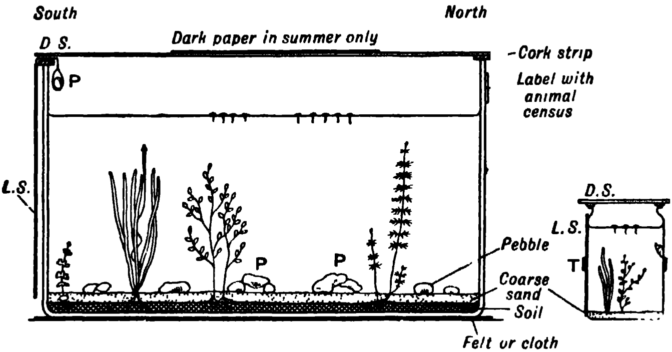


Fig. 66. Aquaria

the green scum consisting of minute plants which grows on the sides of the tanks. Pond snails with coiled sharp pointed shells, are most commonly used in tanks. This animal often hangs by its foot from the film on the top of the water. It has lungs and not gills so that it can come above the surface and breathe air like most of its land relations. Fresh-water mussels are bivalves and breathe by gills and will thrive in the company of water snails.

Water-boatmen, which are brown beetles shaped like a boat and which use their legs as paddles, may occupy

a tank with water snails. Fish, water snails, tadpoles and newts also live happily together; water spiders should be placed in a tank alone, but they must be given some food regularly.

QUESTIONS ON CHAPTER 20

1. What features are common to all molluscs?

2. Into how many groups are molluscs naturally divided? Name two members of each group.

3. Explain how a snail or a slug travels.

4. Explain how (*a*) univalves and (*b*) bivalves breathe.

5. Describe the sense organs of a snail or slug.

6. Describe the heart and blood system of molluscs.

7. How do snails increase their families?

8. How do molluscs protect themselves from their enemies?

9. How do (*a*) water molluscs, (*b*) land molluscs obtain their food?

10. Describe how you would prepare an aquarium.

11. Describe how you would stock an aquarium. What special care is needed?

12. Describe a pond snail and water-boatman.

CHAPTER 21

ECHINODERMS

ECHINODERMS consist of a group of animals with bodies arranged in five divisions and protected with spiny skins. They are found only in sea-water and include sea-urchins, star-fishes, sea-cucumbers, feather stars and sea-lilies.

THE STARFISH

Perhaps the starfish is the best known, for this animal may often be seen on the seashore, having been left behind on the sand after the tide has gone out. It is easily recognized by its shape, for its arms spread out like a star. Its upper surface is reddish brown and the under surface is light yellow and so tones with the colours of the sand. The animal is further protected by numerous short blunt spines, and minute pincers which open and close by muscular action.

On the under surface are numerous little tube feet with suckers, which serve both as feet for gliding along over the rocks and sand, and also as sense organs.

The nervous system consists of a nerve centre around the mouth and from this branches run to the five arms. At the end of each arm is an eye, so that the starfish is provided with five eyes and can keep a watch in every direction for food or foe. Its mouth is in a strange place

for it is on the under surface in the middle, where the five arms meet (Fig. 67).

The starfish feeds on very small marine animals as well as oysters and mussels which it usually finds at night. When eating an oyster the starfish forces open the shell with its tube feet and draws its victim into its mouth

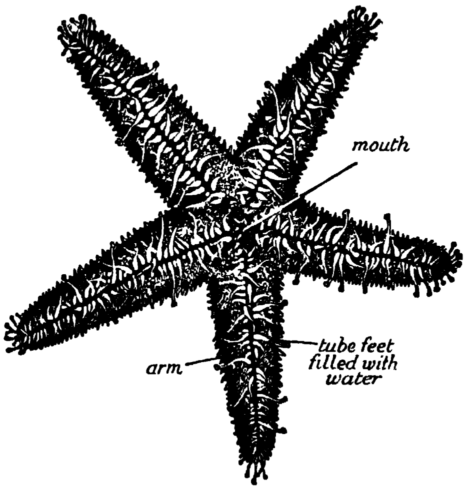


Fig. 67. A starfish viewed from the under side

leaving the shell empty. The digestive tract is very short so that its stomach is quite near to its mouth. Often it secretes digestive juices on to its food which is then digested *outside* its body, but sometimes hard indigestible portions pass into the stomach and these are discharged again through the mouth.

Reproduction. A starfish is either a male or a female animal. The female produces the eggs which she lays

in the water where they are fertilized by the male. The eggs soon develop and from them hatch larvae which are quite unlike the parents. They have oval-shaped stomachs between two tiny water tubes, and swim about in the water by means of cilia. In their development these little creatures undergo *metamorphoses*, or pass through definite stages until they reach maturity when they resemble their parents.

QUESTIONS ON CHAPTER 21

1. What features are common to all echinoderms?
2. Name six members of this group and state where they are found.
3. Describe the appearance of a starfish.
4. Where are the eyes and mouth of a starfish?
5. How does the starfish obtain and digest its food?
6. How does the starfish increase its family?

CHAPTER 22

ARTHROPODA

ARTHROPODA is the name given to a very large group of animals which are distinguished from all others by having their bodies divided into many segments, and by having their limbs in pairs and much jointed. Each of these animals has also an outside covering or skeleton made of a hard mineral substance called *chitin.*

Arthropoda form the last and most highly developed group of invertebrates. They are very numerous, but there are some differences among them in their structure and habits, because some live in water, others on land, and some have adapted themselves for flying in the air.

Naturally by these characteristics they can be arranged in four smaller groups or classes, with the following names :

(1) **Arachnida.** This class includes scorpions, spiders, king crabs, mites, and all their relations.

(2) **Crustacea.** This group includes crabs, lobsters, crayfish, shrimps, prawns, woodlice, water fleas, cyclops, barnacles and many others.

(3) **Myriapoda.** This class consists of centipedes and millipedes.

(4) **Insecta.** This class includes the countless insects which are creatures with bodies divided into three regions and have six legs.

Although Arthropods can be thus divided, they all possess certain features in common. All these animals have bodies composed of segments joined together, but the segments differ considerably, unlike those of worms which are all very similar. In arthropods the segments are grouped into sets, each set having special functions and differing in form from the segments in the other sets. Some segments may be closely joined together for a particular function so that they appear to be in one piece. The foremost segments unite in this way to form the *head*. These are concerned with feeding and so bear sense organs, all of which help the animal to find its food. The next set forms the *thorax* which bears the limbs, that is, legs and wings, to carry the creature to its food. This part contains the respiratory organs and others required for digestion of food. The hinder set combine to form the abdomen, the part containing the food tract and the reproductive organs. Finally, all groups are connected and work in harmony under the control of the brain and nervous system. The nervous system is highly developed. The segments forming the head unite so closely together that their nerve centres, which in worms are spread out at intervals along the body, are collected into a large mass and form a small brain.

CRUSTACEA

The Crustacea generally are aquatic animals, and so breathe either by gills or by absorbing air through their skins. The young of these animals are quite unlike the adult, and so they pass through a series of changes in their early stages of development.

Fig. 68. Some common centipedes and millipedes. *J*, *Julus* (a millipede); *L*, *Lithobius* (a centipede); *G*, *Geophilus* (a centipede)

Among the best-known members of this group are the crayfish and fresh-water shrimps, and these are easily obtainable for observation. The crayfish will be described in a later chapter.

Myriapoda

The Myriapoda include centipedes and millipedes. These animals have long bodies divided into a large number of segments each bearing a pair of legs. The

head has two or three pairs of jaws and carries the sense organs, consisting of a pair of antennæ and numerous eyes. Myriapoda are land animals and so breathe in oxygen from the atmosphere. Air enters through openings at the sides of their bodies and is then spread to all parts along a system of tubes.

Centipedes are found all over the world. They are carnivorous animals and so are hunters. For this purpose they can run very quickly and are armed with fangs charged with poison. The common centipedes are brown and live in damp shady places, especially under logs of wood, stones, loose bark of decaying trees and garden refuse. Here they search for worms and insects. In the chase they seize their prey and inject from their fangs poison which kills the victims (Fig. 68).

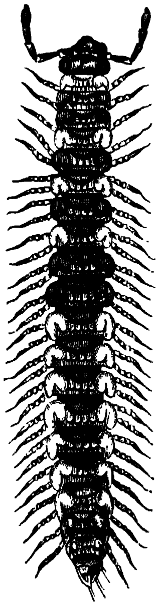


Fig. 69. A millipede

Millipedes are known by gardeners as wireworms. They also have long bodies formed of numerous segments, most of which bear two pairs of legs. Unlike centipedes, these animals are vegetarians and feed chiefly on the roots of plants. For this reason they do not need to move quickly or to be equipped with poison fangs as hunters. They can, however, eject a fluid with an unpleasant smell, and this is their way of protecting themselves against their enemies. Since they feed on roots, they often do much harm in the garden (Fig. 69).

Insecta

Insecta is the name of a group including numerous living creatures with such diversity of habits that they may be found almost everywhere and at all times. Generally they are land dwellers, but many are not content to stay on land and have developed wings to enable them to fly in the air.

Insecta are distinguished from other arthropods in having their bodies divided into three definite sections, the *head*, the *thorax* and the *abdomen*. On the head is the mouth, with either a pair of chewing jaws or a tube for drawing in liquid food, and the sense organs. These consist of a pair of feelers or antennæ, which the insects use also for smelling, and a pair of prominent compound eyes, which are divided into a number of six-sided lenses or facets.

The thorax or middle section bears the limbs for locomotion. These consist of three pairs of jointed legs, and some insects have developed wings also, so that they can fly in the air and search more widely for food.

The abdomen is the hinder part and contains some of the digestive and the reproductive organs.

Feeding. Insects have two methods of feeding. Some have jaws and bite their food; others draw it through a tube in a liquid form. Primitive insects have three pairs of jaws. One pair consists of strong tooth-like *mandibles* used for tearing food, and the two other pairs, called *maxillae*, are used as shovels. The more highly developed insects, bees and butterflies, for example, have maxillæ drawn out into tubes, through which they draw in juices from flowers and other liquid food.

Respiration. Insects have no lungs, but they take in

air through ten small holes along the sides of the body. These can be opened or closed and are connected with a network of tubes called *tracheæ*, through which air passes to all parts of the body.

Many insects have a highly developed nervous system and appear to show considerable intelligence. The little creatures quickly respond to stimuli, because their bodies are covered with hairs resting on sensory cells. When the hairs are touched the stimulus passes along the nervous system and the insect controls its actions accordingly.

Some insects—bees and ants, for example—are called social animals because they live together in communities. These little creatures are wonderful architects and builders and live together in carefully planned and well-governed cities. In these settlements each citizen has its rights and duties, and the labour necessary for the health and well-being of the community is divided among them.

These social insects work by instinct, but seem to show much intelligence, both in carrying out their duties and in the care of the community. At once they recognize members of their own colony, it may be by their smell or by the sounds they make. Some insects are able to produce such scents as to ward off their enemies or to attract their friends, and certain sounds they make are either attracting or warning signals to others. These sounds are usually produced by friction of their limbs. The squeak of the grasshopper, for example, is curiously produced by drawing its hind legs across the edges of its fore-wings. These are not vocal sounds, neither are those made by the humble-bee. The buzz it makes is the result of the rapid vibrations of its wings.

Many insects have curious ways of protecting them-

selves from their enemies. Some, which serve as food for birds, protect themselves by mimicking others which have a nasty taste; others will even feign death to escape their enemies.

Reproduction. Reproduction in insects introduces an interesting feature in the development of animal life. In all lower forms of life reproduction may be the result of the union of male and female cells brought about by a mechanical or chemical attraction. Among insects, however, a kind of selection is shown when choosing the mate, and there follows a distinct form of courtship between the sexes. This exhibition of choice by insects may be compared to the mating season of birds and the sense of beauty, which becomes apparent in the higher animals.

Insects start their lives from eggs which are laid by the female. At first they appear as larvæ totally unlike the parents. These undergo *metamorphoses*, for in their development they pass through a series of changes, until they reach maturity and are perfect insects. The larva is generally a ravenous feeder and grows so rapidly that it must change its skin for a larger one several times. When fully grown it ceases to feed, makes its last moult and changes into a *pupa* or *chrysalis*. In this stage it is dormant and eats no food. Finally it bursts the pupa case and emerges as a perfect insect.

QUESTIONS ON CHAPTER 22

1. What features are common to all arthropoda?

2. Name the smaller groups into which arthropoda are divided. Give the names of two animals belonging to each group.

3. Describe a member of the group Crustacea.
4. Describe a centipede, and a millipede.
5. What features are common to all insects?
6. Describe two methods by which insects obtain their food.
7. In what way do some insects seem to show considerable intelligence?
8. How do some social insects recognize members of their own colony?
9. How do some insects produce sounds?
10. Describe an interesting feature in the process of reproduction by insects.
11. Describe the process of respiration by insects.
12. What do you understand by metamorphosis? What are the stages of development in the life-history of an insect?

CHAPTER 23

ARACHNIDA

ARACHNIDA form a group of animals including spiders, scorpions, mites that live on cheese and all their relations. All these animals bear the same family likeness and are easily distinguished from those in other groups. The body is divided into two distinct parts. The head and thorax which are joined closely together without a neck form one part, and the large unsegmented abdomen forms the other part. These are connected by a narrow waist (Fig. 70).

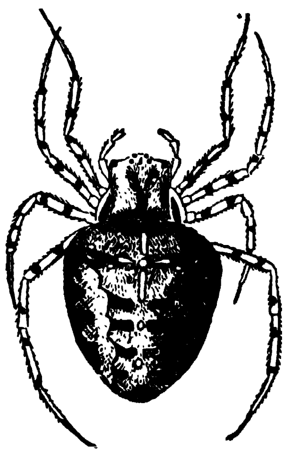


Fig. 70. A garden spider

The *head-thorax* portion is often protected by a kind of shield. The front part is the true head, because this contains the brain and bears the sense organs. Spiders have no antennæ as insects have, but instead they have a pair of palis, or feelers, and very horrible poison fangs, which they use to inject poison into their victims. On the top of the head they have six or eight simple eyes which are quite different from the compound eyes of insects. These creatures have no wings, but they are provided with eight jointed legs,

armed with claws at the end. With these they can chase and kill their prey.

All members of this group are carnivorous animals, and usually hunt their prey at night. There are many kinds of spiders, but scientists have arranged them in two groups according to their way of procuring food. Some make traps and ensnare their prey; others are hunters and chase their prey.

Spiders have very interesting breathing organs known as *lung-books*. They are so called because they are formed of tissue arranged like the pages of a book. Air reaches these through two openings on the under surface of the abdomen and oxygen enters the blood which circulates through the pages of the lung-book. By the muscular movements of a simple form of heart the blood is then driven to other parts of the body.

The spider has a brain or nerve-centre and shows considerable intelligence in some of its habits, especially when spinning its web, choosing its mate, and catching its prey. Some spiders also very cleverly mimic other animals, especially beetles and ants, and some will lie quite motionless or even feign death, when faced with an enemy.

Reproduction. The method of reproduction among spiders is interesting and more advanced than that of insects since in the selection of a mate there is a distinct display of courtship. This is one of the curiosities of Nature; when the male spider approaches the female he does so with much caution, and makes love at the risk of his life. His antics are modest but cunning. He displays his charms in his tufts of hairs and bright patches; he waves his front legs as he parades in front of her and watches her closely for any response she makes.

She watches him severely. If he fails to please her she pounces upon him and kills him. If he succeeds in pleasing her she receives him into her parlour. The male spider is small and very lazy, and it frequently happens that immediately after marriage he is killed and eaten by his mate.

The female spider lays the eggs which she protects with wonderful care. She encloses them in a cocoon which she carries about with her under her abdomen, where it will be safe. When the young are hatched they are miniature spiders and resemble their parents. They do not grow to be like them in stages as do the young of insects. As they develop they cast their skins several times before they reach maturity.

Mites are closely related to spiders and resemble them in structure. They are very small and live in the soil, in water and also as parasites on other animals. Mites which live in cheese are akin to those which cause a disease of the skin known as itch in man, and mange in animals.

QUESTIONS ON CHAPTER 23

1. Give the names of three members of the group Arachnida.
2. What features are common to all these animals?
3. Describe the general appearance of a spider.
4. Describe how spiders procure their food.
5. Describe the process of respiration in spiders.
6. Describe the courtship of spiders.
7. How are spiders reproduced?
8. In what ways do spiders differ from insects?
9. Write anything you know about mites.

CHAPTER 24

CRUSTACEA

THE CRAYFISH

THE crayfish has many near relations. Perhaps the best known are the crab, shrimp, lobster, prawn and barnacle, but all animals protected with a hard covering and provided with more than eight legs are also related (Fig. 71).

Observation

Perhaps a crayfish may be obtained for observation, since they are comparatively common and inhabit many of our lakes, streams and canals, especially those in limestone districts. If possible it is best to observe them alive, for then one may see how they are formed and how they use their limbs. In any event dead ones can be bought from a fishmonger, and these can be handled and examined more closely.

Structure. The crayfish is brownish green in colour and measures about three inches long. Its body and limbs are protected by a hard casing formed of a substance called *chitin*, strengthened by calcium carbonate, which fits like a coat of armour. The creature is divided into twenty rings or segments, which are grouped together in sets to form the head, the thorax, and the abdomen. The head and thorax are really fused into one large piece

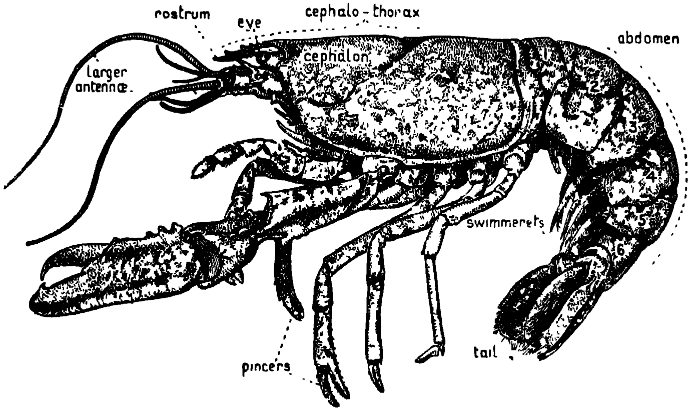


Fig. 71. A crayfish

covered by a hard shield (the *cephalo-thorax*), and the abdomen, formed by six segments, ends with a fan-like tail. Each segment bears a pair of limbs which are jointed and protected by this stony substance.

Each pair of limbs has its own particular purpose. One pair serves as sense organs; another as weapons of defence; another for securing food; others for walking, and others for swimming.

The head contains the brain and bears the sense organs. The first pair of these project as movable stalks bearing compound eyes at the end. Just below are two pairs of antennæ which the animal uses for finding its food and locating its surroundings. Near these is the mouth with three pairs of jaws, which, of course, are used for obtaining and eating food.

The most conspicuous limbs are the two huge *pincers*. These cruel-looking weapons are used by the animal for

gripping and tearing its food as well as for a means of defence. The next four pairs of limbs are legs for walking, and the six pairs of short limbs attached to the abdomen are used for swimming. These vary slightly in form, as some are adapted for paddling the animal forward, while the last pair serve as oars for rapid swimming.

The hard shell-covering, which forms an outside skeleton and keeps the shape of the animal, consists largely of calcium carbonate. When the crayfish is young and growing, its shell must be replaced several times, for when it is hardened it does not increase with the growth of the animal. It therefore becomes tight and uncomfortable and has to be changed for another. When this happens the animal bursts the shell, wriggles out and casts it aside whole. The creature then grows very rapidly before the new case is formed. At first the substance is soft and moulds to its form. When the animal is full grown, moulting becomes an annual event. Then the shell splits along the back and limbs and the creature draws itself out, leaving the case empty. When the animal has moulted and is soft, it hides under stones until its outer coat has hardened again.

Experiment

To show that the shell of a crayfish is composed of calcium carbonate

Apparatus. Test-tube, piece of crayfish shell, hydrochloric acid.

Place a piece of shell in a test-tube and pour in a few drops of hydrochloric acid.

Result. An effervescence begins and the gas carbon dioxide is given off. You will remember that carbon dioxide can be made by pouring hydrochloric acid on calcium carbonate or marble (Book 2).

Food. A crayfish lives in water, but it likes its diet varied and eats both plant and animal food. By nature, it is a carnivorous animal and it is equipped with weapons for catching its prey, but it does not mind whether its food is alive or dead. It uses its large claws for breaking the shells of water snails or other fresh water animals and small living creatures and tears them to pieces. The food is softened and minced in the mouth and then passes into the stomach, where it is ground up by teeth.

Respiration. Since the crayfish is a water animal it breathes by means of gills. These are feathery-looking structures on each side of its head and are protected by a shield. The gills absorb oxygen out of the water which is constantly baled over them by the fifth pair of limbs.

Reproduction. Crayfish increase their numbers from eggs laid by the female. She takes great care of them and protects each one with a case of material similar to that forming her own shell. She then attaches them by the same substance to her swimmerets on the under surface of her body where she knows they will be safe. There she keeps them until they are hatched, and all the time the young are growing they cling to her limbs by curious tips on their pincers. In this way the mother protects them from being carried away from her by the stream.

Renewal of damaged parts. These animals have so many legs and limbs that they frequently get them injured. This, however, is not a serious matter with

crustaceans, because all of them have the remarkable ability to replace or renew lost and damaged parts. If a crayfish, lobster or crab is caught by the leg it will break it off at the joint to make its escape, and eventually grow a new one.

QUESTIONS ON CHAPTER 24

1. What features has the crayfish in common with other members of its class?
2. Name three creatures related to the crayfish and give the name of the class to which they belong.
3. Describe the sense organs of the crayfish.
4. Of what substance is the shell of the crayfish chiefly composed? How could you prove this?
5. Describe the development of the crayfish and how its shell is formed.
6. Describe how the crayfish breathes.
7. What is the chief food of the crayfish? How is it procured?
8. How does the crayfish increase its family?
9. What do you understand by renewal of damaged parts?

CHAPTER 25

INSECTA

INSECTS form another class belonging to the large group Arthropoda, and in some ways they are more developed than most of the other invertebrates.

THE ANT

The ant is a typical and familiar insect; but perhaps only few people realize what an intelligent and wonderful little creature it really is. There are many kinds of ants, but the best known English ants are those which may be seen running about the gardens, and the meadow ants which make their homes under little mounds in the grass fields.

Observations

The garden ants are quite easily obtained, and can be kept comfortably for a short time in a box with glass sides and perforated lid of canvas.

In such a *formicary* you will notice that the ants are a reddish-brown colour which tones with that of the soil. In this way Nature protects them, for they are not very clearly seen by birds and other enemies. If you examine one of them closely through your lens you will see the parts more distinctly. Like all other insects its body has three parts or sections—the head, the thorax, and the abdomen.

The *head* is rather flat in shape and carries the sense organs. With these the ant can see, feel, smell and taste. On the top is a pair of antennæ. These have a joint in the middle and are used by the ant for finding out anything it wants to know. When ants wish to communicate or talk to one another, they touch their antennæ and in some strange way they tell each other what they want to say or do.

The ant also smells with these antennæ, and by them it can find food and recognize members of its own colony. The hairs on them are connected with very sensitive cells and when they are touched the stimulus is instantly passed along the nervous system to the brain which tells the ant how to act.

The ant also has a pair of wonderful eyes. They are compound, and are divided up into a number of lenses placed close together and connected so as to look like one large eye.

This insect has a comparatively large mouth for receiving its food, but it is also armed with a pair of very strong sickle-shaped jaws which it uses as weapons for fighting and as tools for working in many different ways.

The *thorax* forms the middle section of the insect and to this are attached the six, long, jointed legs. The queen and male ants have two pairs of wings as well. The ants with no wings are females, but they cannot lay eggs. If a leg is examined on the screen shown from a micro-projector, the joints and little nippers at the end may be seen distinctly.

It is interesting to watch how the ant uses her legs. She runs along very quickly, but occasionally she stops to

stroke her body with the fore pair. On the joints of these may be seen tiny spurs with fine hairs and on the leg itself are rows of stiff hairs. These serve as the ant's brush and comb for she uses them when doing her toilet, in the same way that a cat uses her paws for washing her face. When the ant has finished she draws them through her outer jaws to clean them.

Ants and other insects breathe by means of tracheæ (see p. 154).

The heart. The heart is shaped like a sausage, and by contraction and expansion it forces the blood along. The blood is almost colourless and flows into open spaces in the body, to distribute the food and to collect the waste products.

The *abdomen* or tail-part is formed of horny segments arranged like a telescope. This contains the digestive tubes and the reproductive organs.

Between the thorax and the abdomen is a long narrow waist which helps the ant to go round corners quickly and gracefully. Some kinds of ants have a curious little hump in their waist and some have two humps. All British ants which have two humps are able to sting; but the other kind protect themselves by biting with their strong jaws and then squirting formic acid from their bodies over the wound which they have made. This acid, of course, makes the wound painful.

The nerves. The ant has a definite system of nerves. It has a small brain in the head and other nerve centres from which nerves extend to all parts of its body. This creature also has many instincts. It is born knowing how to do many complicated actions. Many other animals, such as birds, have instincts. Ants seem to show con-

siderable intelligence too, as do other social animals which live in organized communities.

The ants' home. All ants make for themselves a marvellous home. The yellow meadow ants build a little mound in the grass fields, and the brown garden ants make their home under the ground. Here great numbers of these little creatures live together. They build their city on a complicated plan. It is entered by narrow gateways which lead into a courtyard. From this, long, winding passages, guarded by sentinels, lead to a hall or large common room, with a roof supported by pillars of earth. From this, passages lead to smaller chambers used as store rooms, sleeping rooms, living rooms, egg rooms and nurseries.

All day long, in and out of these rooms and along the passages, the active little ants are hurrying here and there like busy citizens in a great city.

Division of Labour

If the ants in a community are observed more closely, soon it will be seen that each ant has some definite task, for the ant city is perfectly governed and every member has its rights and duties as a citizen.

Finally it may be learnt that in every community there are three kinds of ants—namely, the queens or females which lay the eggs, the drones or males which do no work, and the workers, which are females also, but never lay eggs. Each of these little creatures has its own purpose and knows by instinct what work it has to do.

The workers do all the work of the city, and, as soon as they are fully grown, they start on a series of duties

(Fig. 72). When they reach a certain stage in their life-history, some work as foragers and go off in gangs outside the city to gather supplies of food. Others are builders and set out to collect building materials. These may be seen breaking off pieces of stems and leaves with their mandibles, and then carrying them back to the nest. Others may be seen climbing the stems of flowers for honey to take back to their home. If these should meet others which are hungry, they at once feed them with the honey they have gathered, for the chief business of these generous little creatures is to help and care for others.

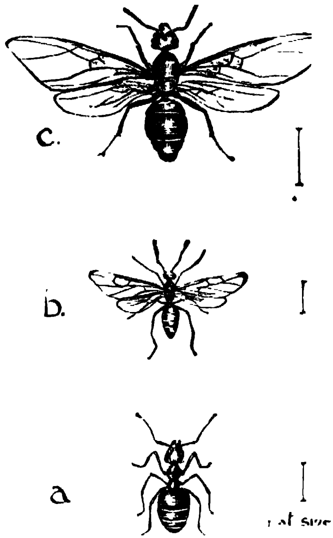


Fig. 72. The yellow meadow ant. *a*, worker; *b*, winged male, *c*, young queen

Inside the city others are just as active. Here gangs of ants work as road makers and are constantly busy keeping the passages clean and in repair. Others tidy the rooms. Others watch over the eggs; then, when these are hatched, they feed and care for the babies; while processions of other ants hurry along the passages carrying little white cocoons from place to place. These are the *pupæ*, or young ants, which are sorted out according to their age and kept in special nurseries.

A very important and healthy band of ants forms

the army. Some of these brave soldiers keep guard over the city, while others attack all robbers and banish unwelcome strangers. There are others, too, which act as sanitary workers and undertakers. It is their duty to carry out and bury the dead.

The ant community is remarkably organized and the work is equally divided among the members. None is idle, and each ant takes its share of the tasks for the welfare of all. Moreover the work is so arranged that each ant is able to undertake any duty, and in turn does one job after another in the many departments as it passes through the various stages in its life-history.

These insects are not taught what to do, but instincts, or perhaps the chemical changes which occur in them during their development, direct and control their successive actions.

In some ant communities, a section forms an active army and marches off to make an attack on others. In their battles they kill many and capture others, which they bring back as prisoners, and use as slaves. There for the rest of their lives the slaves wait upon the conquerors, cleaning and feeding them until the masters lose all power of looking after themselves.

The queens. There are usually several queens in every city. These ants are easily recognized by their long wings, and they are larger than the males which have wings too. The queens spend all the day in the city, and never go out even for air or exercise. Their business is to lay eggs, and this keeps them very busy. Each queen has a little band of workers to wait upon her. They follow her about, give her food, attend to her toilet and stroke her gently with their antennæ.

Fig. 73. Diagram of a section of a small part of the nest of the yellow meadow ant ($\times 4$). *E*, eggs ; *L*, larvæ ; P, pupæ ; *W*, worker ants ; *Q*, queen ant

Life-Story of the Ant

The queen ant lays all the eggs which are almost too small to be seen. They are laid in clusters and at once

they are carried off by the nurses to the egg room where they are guarded and kept at the right temperature for hatching. If this room gets too hot or too cold they are carried to another part of the nest (Fig. 73). As soon as they are hatched, the baby ants are removed to one of the other nurseries.

The young. The ant babies are very helpless little creatures and not in the least like their parent which laid the eggs or like other ants. They are little white grubs, or larvæ, and at first only wriggle and open their mouths for food. The nurses take great care of them. They feed them, clean them and stroke them tenderly with their antennæ. At night they carry them to the lower nurseries where they are warm and safe, then in the morning they take them back to the top rooms where they may have more fresh air. On warm days the nurses carry the babies outside the nest and lay them in rows in the sun. When the nest is in danger, the ants' first care is for the babies. Each nurse seizes one in her mouth and runs to a place of safety.

The pupa or chrysalis. When the grub is full grown, it spins a case or cocoon round itself and then goes to sleep inside. In this state, it eats no food and seems dormant; but really great changes are going on, and it is slowly forming legs and feelers and developing into an adult ant. If the cocoon is opened a few days after it is made, it will be found that the grub has changed into a little mummy-like creature known as a pupa or chrysalis, though it has already formed the limbs and feelers of the adult ant.

The nurses still tend them with great care and carry them about from place to place, so as to keep them at the right temperature.

While they are asleep in the pupa stage they are entirely altered from helpless maggots to very lively little ants. When they are ready to come out, the nurses are there, eager to help them. They break open their cases and the creatures emerge as perfect insects.

This series of distinct changes which take place in the development of an ant is common to all insects and is known as *metamorphosis*. The life-cycle of the ant is an example of that of all insects. They all begin life in the egg which develops into the larva; this changes to the pupa and then to the *imago* or perfect insect.

Reproduction. Ants are hatched from the eggs which are laid by the queen. During the summer, the male ants come out of the cocoons, but they do no work. These drones have wings, but they idle and loiter about, seemingly quite useless. This is not so really, for everything in Nature has some purpose, and the drones are very necessary, for without them the race of ants could not continue. They are needed to fertilize the eggs; and later they go with the queen on her "wedding flight". Since they are really important they are kindly treated and fed by the workers; but they do not remain long in the nest, for on a hot still day, all at once, they rush together in thousands and burst through the gates of the city. In this way the drones leave the nest and the young queens fly off with them. This is their "wedding flight" and they all fly high in the air where the queens choose the drones to help in forming the eggs. The swarm of ants, however, is soon pursued by birds and most of them are eaten.

New nests. Some of the young queens, however, manage to escape the birds, and these, with the help of

a few workers, set up a new home. In this nest no drones are admitted, so any that still survive find themselves outcasts and soon die. The queens then seem more content and never want another gay flight. At once they tear off their wings and settle down in the new home where, for the rest of their lives, they are busy laying eggs.

The food of ants. The ant likes to feed on the sweet juices from plants and flowers. Perhaps the food it likes best of all is the sweet fluid given out by the little green-fly or aphis which lives mainly on leaves of plants.

Aphides

These little flies or aphides, live in our gardens on different plants which they sometimes destroy (Fig. 74).

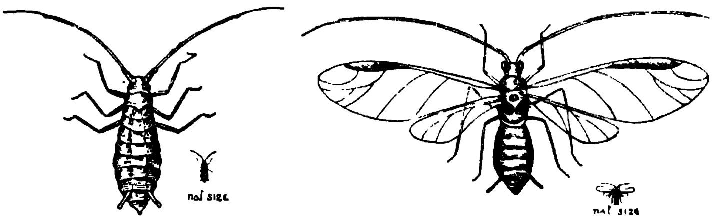


Fig. 74. An aphis off sycamore. Left, wingless form; right, winged form

They are hatched from eggs laid on the plant on which they feed, and from this they often take their colour and their name. One kind is the rose aphis, another is the cabbage aphis and so on.

The ants' cows. If you examine these little creatures you will see that they possess two tubes at the end of their bodies. In warm dry weather these insects settle in countless numbers on plants from which they suck out the

sweet juices, until their tiny bodies are so full that the juices ooze out of the tubes in sticky drops known as honey-dew. This juice is just what the ant likes to eat and so it stands behind an aphis and strokes its sides with its antennæ and sips the honey from the tubes. Then it goes to other aphides and takes more from them until it has got all the honey it wants. So the ant goes from one to another just as a milkman goes from cow to cow until his pail is full of milk.

Some ants rely on the aphides for much of their food, and it is quite common for them to keep large herds of the green-flies in their own nests, where they are tended by the workers with much care. Sometimes they confine them to plants near their nests and guard them from attacks by other insects.

There groups of ants go regularly to milk their cows and often not only satisfy themselves, but take some to those unable to get it.

In the autumn, the ants collect the eggs of the aphides which have been laid on the plants and store them in their own nests where they are safe until the spring. Then, when the young aphides are hatched, the worker ants carry them to the plants growing near their city, so that their own food supplies may be near at hand. In this way the two kinds of insects are a help to one another.

QUESTIONS ON CHAPTER 25

1. What features has an ant which are common to all insects?
2. Describe a garden ant.
3. What are the antennæ and their uses?

4. How do ants recognize members of their own colony?

5. Describe the head and sense organs of an ant.

6. How do ants and other insects breathe?

7. Describe the heart and blood of an ant.

8. Describe the nervous system of an ant. In what way do ants show intelligence?

9. What do you understand by instincts in animal life? Mention any instincts shown by ants.

10. Describe an ants' city.

11. Describe the three kinds of ants found in a community.

12. What do you understand by "division of labour" in animal life?

13. Describe the duties of a worker ant during its adult life.

14. Relate the life-history of a worker ant.

15. Describe the (*a*) eggs, (*b*) larvæ, (*c*) pupæ in the development of ants.

16. How do ants increase their numbers and form new nests?

17. How do ants obtain their food? What do you know about aphides?

CHAPTER 26

VERTEBRATES : FISHES

VERTEBRATA is the second great division of animals. All vertebrates have a backbone or vertebral column and have other features in common also. Distinct differences may be observed between different kinds of vertebrates, and, accordingly, they are divided into five smaller groups called classes, namely: (1) *Fishes*, (2) *Amphibians*, (3) *Reptiles*, (4) *Birds*, (5) *Mammals*.

FISHES

Fish are the lowest group of vertebrates and form a connecting link with invertebrates. The backbone extends from the head to the tail and divides the body into a right and left half; and the limbs, muscles and nerves in each half are correspondingly formed and placed.

All fish live in water, but scientists tell us that all life started in the sea, and that most animals which now live on land and in the air are more advanced in development than those which still live in water. Fish have not yet learnt how to live on land. A frog, for example, is a more developed animal than a goldfish, because it spends only the early part of its life in water.

KINDS OF FISH

There is a great variety of fish. Though all fish possess the characteristics common to their kind, they differ in

size, colour, shape and in the structure of their heads, bodies, tails and other details; yet they all have fins and all are covered with scales.

The eel, for example, has a long, thin, round body and so is adapted for boring in sand and mud. Others too are adapted to the conditions in which they live. The sole and similar fish are flat, because they feed and live on the sea floor. They have taken this shape gradually to adapt themselves to their environment. When young, the head of the sole resembles that of a trout; but, as it grows older, the head becomes flattened, the left eye moves nearer to the right one, and the mouth becomes distorted, which gives the fish a very queer appearance.

The largest fish in the ocean is the basking shark which is about thirty feet long.

The Trout

General appearance. The brown trout is a familiar fish of our rivers and streams. The skin has a silvery appearance and has beautiful markings. The body is grey or brown, with large black spots and small red ones scattered on the back and sides. The under surface is yellowish white (Fig. 75).

Scales. Under the transparent shiny covering is a layer of scales. Each scale is marked with lines which indicate the age of the fish just as the rings of cells in the stem show the age of a tree. The scales themselves are made of calcium carbonate, a form of chalk. When the fish are young, the scales are very small; but as they grow older so the scales become larger, as more rows of calcium carbonate are added annually.

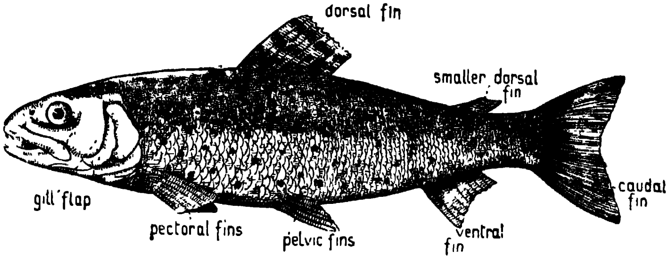


Fig. 75. A trout

Structure. The body of the trout may be considered in three parts—the head, the trunk, and the tail—though they are not very clearly defined. The head is attached directly to the trunk and not joined by a neck, and the tail extends from the vent, or outlet of the food canal.

In common with other fish, the trout swims by means of *fins* which are formed by bony rays covered and joined with skin. It has two pairs of fins which correspond to the limbs of higher animals. The *pectoral fins* on each side of the body near the gills correspond to the fore limbs of a dog, or wings of a bird, or to the arms of the human body. The two *pelvic fins*, near the middle of the fish and closer together, correspond to the hind legs of higher animals. These two pairs of fins are used by the trout for balancing. Besides these is the *tail fin*; along the back are two *dorsal fins*; and immediately beneath is the *ventral fin*; all of which fins are used by the fish as it swims through the water.

In addition to these external organs of motion, the trout is provided inside the body with a long bladder filled with air which helps it to float in the water. This bladder lies near the backbone and is called the *swim*

bladder. It enables the fish to raise or lower itself in the water.

The head contains the brain and bears the sense organs. The two large eyes have no eyelids, but they are protected by a transparent skin. The trout, like other fish, is unable to close its eyes, so it usually seeks a shady place in order to avoid bright sunlight. It has two ears, but they are not visible, because they are covered with skin to keep out the water. It has two nostrils which it uses mainly for testing the purity of water.

The trout has a wide mouth and jaws set with rows of needle-like teeth. On the tongue also is a double row of small teeth which are used by the fish for seizing and tearing its food. The fish swims along with its mouth open, and the water, containing insects, worms and other small creatures, passes in. These creatures are seized by the jaws and torn to pieces by the teeth. At the back of the mouth are the gill arches from which project little sharp bony rods known as *gill-rakers*. These act as strainers and rake out the food, which is swallowed and passes down the food canal. The water flows out through the gill slits, which are covered by a bony gill cover

Digestion of food. The food then enters the digestive tube called the *alimentary canal*, which reaches from the mouth to the opening called the *vent* near the tail. The tube varies in width. Near the mouth it widens into a *stomach* with the reddish-brown *liver* on each side. It then becomes narrower and bends over upon itself. Attached to this are outgrowths and glands which produce juices for digesting the food.

Respiration. This is effected by means of the gills which are covered with flaps seen on each side of the fish

where the head joins the trunk. Under each flap are slit-like openings which lead into the chamber containing the gills. These are four sets of comb-like structures attached to bony arches, and the numerous small blood vessels under a very thin skin give them a salmon-pink colour. The fish obtains its oxygen in respiration from the water as it flows over the gills and out of the openings. The oxygen dissolved in the water passes through the very thin walls of the blood vessels into the blood of the fish. There, in the gills, it replaces the carbon dioxide which passes out.

The heart. The trout has a heart with two chambers and it lies in a special cavity beneath the throat. The blood bringing impurities collected from the body enters the chamber called the *auricle*. It then passes into the other chamber called the *ventricle*. This has muscular walls and by their contractions the impure blood is driven along a blood vessel, back to the gills where the carbon dioxide passes out.

Reproduction. A trout can be of only one sex, so it is either male or female. If it is a male it has a soft roe formed of male cells or sperms ; if a female it has a hard roe containing many eggs. At certain seasons of the year the female trout lays her eggs in masses in a sheltered part of a stream. The male then sheds some *milt* from the soft roe over the eggs, which makes them fertile so that they can develop into young fish. Each egg contains a large pink yolk which is the food provided for the germ. After forty days, the fish hatches, but it is still attached to the yolk which supplies it with food. The young fish grows very slowly, for, when it is twelve months old and is called a yearling, it measures only

three inches. It is then a miniature of its parents and soon begins to grow rapidly.

QUESTIONS ON CHAPTER 26

1. Give the names of the five divisions of vertebrates, in order of their development.
2. How have vertebrates been classified?
3. Why are fish considered the most primitive type of vertebrates?
4. Describe the appearance of any fish you know.
5. Explain how fish breathe in water.
6. Describe the sense organs of a fish.
7. How do fish obtain and digest their food?
8. Describe the organs of motion of a trout.
9. Explain how fish reproduce themselves and increase their numbers.
10. Explain why a fish is suited to life in the water.

CHAPTER 27

AMPHIBIANS

AMPHIBIANS are animals more advanced than fish. They are able, for the latter part of their lives, to live on land. Frogs, toads and newts are amphibians. All these are hatched from eggs laid in water by the females. In their earlier stages of development, they resemble fish, in possessing gills and other structures which adapt them for living in water; but as they grow older, they differ from fish in their ability to change their organs so that they can live on land. Their fins disappear and are replaced by limbs with fingers and toes, which change enables them to walk on dry land. Their gills also disappear and lungs develop so that they can breathe air as other land vertebrates do.

Mondiale

Fig. 76. A toad

Amphibians are covered with a bare skin free from scales or hairs, and some of them change their colour to tone with their surroundings which change is a natural means of protection (Fig. 76).

Respiration. The frog absorbs oxygen through its skin, and for this reason it must be kept moist. Frogs are able to do this by secretions of moisture from skin glands, and instead of drinking in the usual way, they absorb moisture through the pores in their skin, and this compels them to live in warm wet places. Adult amphibians, however, breathe chiefly by means of lungs.

Amphibians resemble fish in being cold-blooded animals. The temperature of our blood is warm; normally it is about 98.4° F., and that of birds is warmer; but the temperature of cold-blooded animals varies with that of their surroundings. The frog has a heart shaped somewhat like our own, but the main part of it is divided into three chambers and not four as ours is. It is muscular and the contractions of the muscles drive the blood away from it through a system of tubes called *arteries*, and cause the blood to flow back to it through another set of blood vessels called *veins*.

Food. The food of amphibians generally consists of insects, snails, worms and other small animals with soft bodies. The food passes along an alimentary canal and is broken up and dissolved by means of digestive juices. It then oozes into the blood stream and is carried to every part of the animal's body, to build up tissues and supply it with energy to perform its activities.

Nervous system. Amphibians have a more highly developed nervous system than the lower animals. From the brain in the head a long nerve passes along the whole length of the back, and branches from this lead to the limbs and other parts of the body. Nerves also connect

the brain with the sense organs, thus enabling the animals to see, hear, smell and feel.

Vocal sounds. Amphibians are the first animals, in the scale of development, capable of producing vocal sounds. The croak made by frogs is a definite call produced in their throats. Bees and other insects make a buzzing sound, but this is produced by the vibration of their wings or other limbs.

Reproduction. This was described fully in Book 2, pp. 183 to 185. A definite metamorphosis from the egg through the aquatic tadpole to the terrestrial adult takes place.

Kinds of Amphibia

There are several kinds of amphibia in the British Isles. There are three species of newts which have long tails, and four kinds of frogs and toads which, of course, are tail-less amphibians. Newts or efts are common in our ponds and streams. These creatures have short legs and a long tail fringed with a fin which is used as an oar in the water. They move slowly on land, where they find worms, centipedes, slugs and insects for food.

The frog and toad closely resemble each other. The common British grass frog has a dark patch of skin on each side of the head behind the eye; but the toad has a very warty kind of skin, and this animal secretes a poisonous substance which protects it from many enemies. There are two species of toads found in England; one is the common toad and the other is the natterjack, which is distinguished by a pale yellow streak along the middle of the back.

QUESTIONS ON CHAPTER 27

1. What features are common to all amphibians?

2. Why are amphibians considered to be more highly developed animals than fish?

3. Why do amphibians inhabit moist places?

4. Describe the organs of motion of an amphibian (*a*) when developing, (*b*) when an adult.

5. Describe the blood system of a frog.

6. How do amphibians obtain and digest their food?

7. What kinds of amphibians are found in the British Isles?

8. Describe the two species of toads found in this country.

9. How do amphibians reproduce their species?

10. Describe the sense organs of an amphibian.

CHAPTER 28

REPTILES

Reptiles are a stage higher up the ladder of development in animal life. Fish spend all their life in water ; amphibians spend the early part of their life in water, but later on they adapt themselves for life on land. Reptiles, however, are able to spend all their life on land and need not even live in damp places, or lay their eggs in water for safety. Moreover, they are born with lungs for breathing air like other land vertebrates, and most of them lay their eggs on land where they are hatched, and protect them by a shell, so that they shall not be dried up by the sun. Some of them—crocodiles and turtles, for example—spend most of their time in water ; but even these must come to the surface to breathe in the open air, and must also lay their eggs on dry land.

All reptiles are lovers of warmth, and most of them like best to live in tropical lands. Snakes, lizards, turtles, tortoises, crocodiles and alligators are perhaps the best known. Only six kinds are found in Britain ; three species of snakes and three species of lizards.

Since reptiles cannot endure cold weather, those in temperate lands hibernate in winter.

All reptiles are covered with scales for protection. Those covering turtles are massed into hard shells. Most of these animals have a small head, four short legs and a long tapering tail. Usually they are very slow,

creeping animals. Their coloration blends with their surroundings and their stealthy movements are their natural protection. Some species have nails and claws on their limbs; but, since reptiles generally are shy and have retiring habits, they have no need for such weapons for defence.

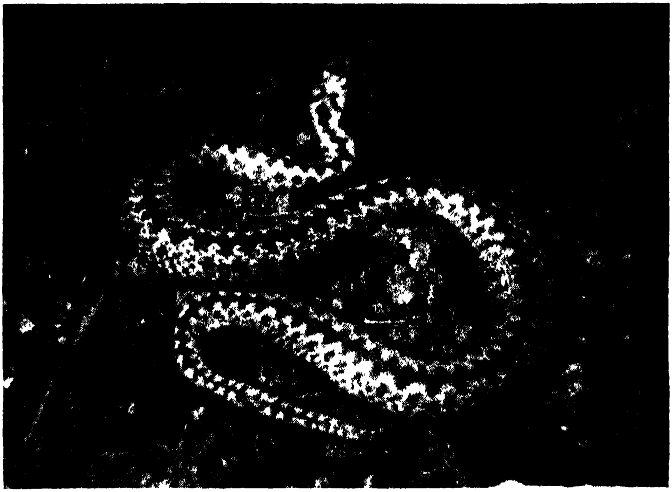
Reptiles are cold-blooded, and their temperature varies with that of their surroundings. The activities of these animals also vary with the temperature of their blood.

Though the temperature of their blood is low, the system of circulation is more highly developed than that of lower animals. The heart of most reptiles is divided into three parts by a partition. One side drives the impure blood to the lungs and the other side pumps the pure blood through the blood vessels round the body. The heart of birds and mammals has four chambers but because that of reptiles has only three, respiration is slow and the blood is never quite pure and free from carbon dioxide. In animal life during respiration, oxygen gives heat to the blood which warms the body, so the slow breathing of reptiles keeps their temperature low.

SNAKES

Snakes are reptiles, though they differ in various ways from all the others. They have no obvious limbs. Their backbones are wonderfully formed of a number of small bones connected by ball and socket joints which enable them to turn and coil in every direction (Fig. 77).

Food. Snakes are carnivorous animals and feed on frogs, fish, flesh of other animals and eggs of birds.



Rudolph Zimmermann

Fig. 77. An adder

When feeding they open their mouths very wide, because the jaws are loosely held together by a ligament and can be moved separately. They swallow their food whole, although it is sometimes bigger than the head of the snake. The jaws are furnished with sharp-pointed teeth which are curved inwards. These are used for holding the prey until it enters the stomach.

There are three different kinds of snakes in the British Isles. (1) The *coronell* or *smooth snake* (of limited distribution), which kills its prey by constriction and then swallows it whole. (2) The *adder or viper*, which kills its victim by injecting poison and then swallows it. (3) The *common* or *grass snake*, which swallows its prey alive and whole.

Not all snakes are poisonous. The adder or viper is the only venomous snake found in this country. This animal prefers to live in dry situations, and is often found on heather moors, in old gravel pits and quarries. It is easily recognized by its broad flattened head, marked with a dark V-shaped blotch. Its body is brown and covered with small scales and is prettily marked with a dark zig-zag along its back.

The viper measures about two feet long and it is a dangerous creature, because it is provided with two large hollow teeth, or *poison fangs*, set in front of the upper jaw. Its bite is poisonous, because poison from a gland at the root of the fangs is forced into the wound it makes.

The food of the adder consists of small animals such as mice, birds and frogs which it hunts at dusk. The adder pierces the skin of its victim and injects into the wound a drop of poison which paralyses its prey and prevents it from struggling.

The grass snake is the largest found in Britain and some of them measure a yard long. This creature is olive green and brown and beautifully marked with yellow patches on the head, rows of black spots along its back and light grey under its body. Its head is covered with scales and its two prominent eyes are protected by a transparent skin which forms a third eyelid. Its mouth is very wide and contains two curved fangs and a forked tongue. Though the grass snake frequently hisses and shoots out its tongue, it never bites a human being, and is quite harmless. Grass snakes are good swimmers and often live in meadows along the banks of a stream where frogs and fish are plentiful.

All snakes and other reptiles have scaly coverings

which do not grow with the animal. When the snake is growing, it outgrows and casts its skin, and a new one is formed. When it reaches the adult stage, it still casts its skin several times a year. Before doing so, it becomes restless, and is partly blind while the new skin is forming. Then, to get rid of the old one, it rubs its jaws on the ground to wear a hole through which it can wriggle out, leaving the skin whole.

Some snakes, like most reptiles, reproduce by laying eggs and so are known as *oviparous* animals. The eggs are about the size of a small nut and are laid often among decaying leaves where they can be hatched by the sun. Vipers, slow worms and common lizards, though reptiles, do not lay eggs. The young of these animals are born alive from the mother, so they are known as *viviparous* animals.

QUESTIONS ON CHAPTER 28

1. What features are common to all reptiles?

2. In what way are reptiles more highly developed than fish and amphibians?

3. Where do most of the reptiles live? How many kinds are found in the British Isles?

4. What do you know about the blood of reptiles? What effect has it on their activities?

5. Describe a grass snake. What kinds of snakes are found in the British Isles?

6. Describe an adder. Where does it usually live? How does it differ from a grass snake?

7. What food do adders like to eat? How do they procure it?

8. Where and why do reptiles hibernate in winter?
9. How do reptiles reproduce their species?
10. By what means does a snake travel? Why is it able to coil itself round an object?

CHAPTER 29

BIRDS

BIRDS are different from all other vertebrates because they are covered with feathers. Most are adapted for flight. The skeleton is made of bones which are strong, but light in weight. They are hollow and, instead of containing marrow like the bones of higher vertebrates, they are filled with air. Their fore-limbs are modified to form wings and are moved by powerful muscles attached to the ridge of the breast bone. Their lungs are large so as to contain much air, while in other parts of their body are air-sacs or spaces filled with air to make them light and buoyant. The blood of birds is warmer than that of any other vertebrate, for the temperature of some is 100° F., while others reach as high as 105° F. It is said, too, that the heart of birds beats faster than that of any other living thing.

The wings and tail bear large *quill* feathers. Those in the wings enable the bird to rise and fly forward, while those in the tail serve as a rudder and steer the bird through the air.

THE PIGEON

Many birds come round our homes, and perhaps the common pigeon, or rock dove, is one of the most familiar among the larger ones (Fig. 78).

Structure. The pigeon has a plumage of soft bluish grey feathers, shot with tints of purple and green on the

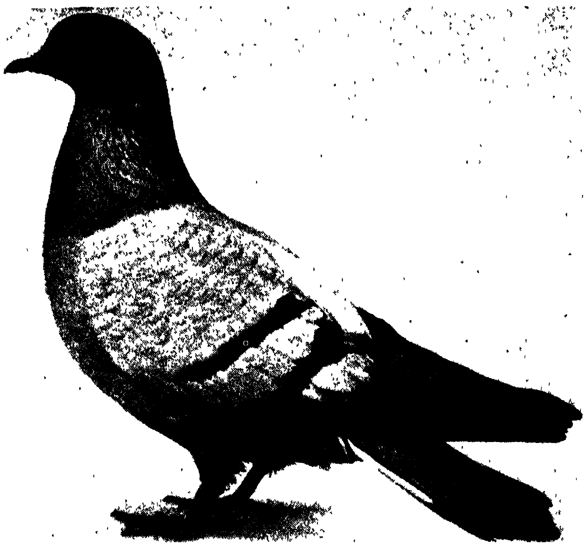


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Fig. 78. A pigeon

neck and marked with dark bars across the wings. In common with other birds, its body is shaped like a boat and it has very graceful movements both on the ground and in the air. For the purpose of study, the pigeon may be considered under three headings, namely, (1) the *head* which contains the brain and bears the sense organs; (2) the *trunk* containing the heart and lungs and bearing the wings and legs, the limbs for moving, and (3) the *tail part* containing the digestive and reproductive organs.

The *beak*, though comparatively short, is the most prominent feature on the head. Its form indicates the

kind of food the pigeon eats, as the short, pointed beak is the best shape for picking up seeds and grains of corn. The two slit-like openings on the upper jaw are its nostrils, though birds, generally, have a poor sense of smell. The eyes are rather large and are protected by upper and lower eyelids as well as a third one which moves across the eye under the two others. Just below the eyes are the openings of the ears; but these are covered with feathers and are not easily seen.

Pigeons have four limbs in common with all birds and other vertebrates. The fore-limbs are modified into wings, but are formed of bones corresponding to the human upper arm, fore-arm and hand, and to the fore-legs of a rabbit, dog or other mammal. The hind-limbs are the walking legs, and these are formed of bones similar to the human thigh, shank, ankle and foot. The feet and ankles of birds are covered with scales instead of feathers. On each foot are four toes each ending in a blunt claw, and underneath are little pads to protect the feet when the bird is walking.

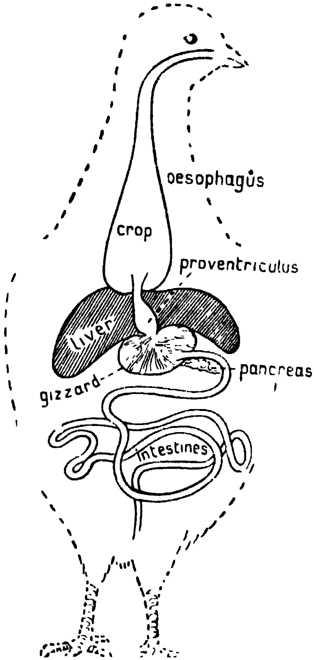


Fig. 79. The digestive organs of the pigeon

Near the end of the tail, on the dorsal side, is an oil gland which secretes a fluid used by the bird for greasing or preening its feathers. This is performed with the aid of its beak; the oil preserves and strengthens the feathers and prevents water from reaching the skin.

Food and digestion. A pigeon has a beak adapted for picking up seeds. These are swallowed and pass down a part of the alimentary canal into a wide chamber known as the *crop*. Here the food is stored and later it is gradually digested. It passes from the crop into the *digestive sac* or *proventriculus*, where it is acted upon by digestive juices. Thence it passes to the *gizzard* which has strong muscular walls for grinding the food into small pieces, so that finally it enters the blood to be carried to all parts of the body (Fig. 79).

Migration of Birds

Many animals are compelled to hibernate during the winter because their food is scarce; but birds can avoid the winter and *migrate* to warmer lands where food is plentiful.

Fortunately all birds do not leave our islands in winter. There are about four hundred species of British birds, but most of them migrate, and only about one-third are *residents* and remain all the year round. There are a few, however, which come to our islands from cooler lands. The little fieldfare, for example, leaves its home in Norway, and spends the winter in our country.

Many of the migrants fly very long distances. Some go to the south of France and as far as the north and west coasts of Africa; and it is one of the great mysteries of Nature that these little creatures find their way there and

home again. Birds have wonderful instincts and know how to do many things without being taught. For example, they know by instinct how to build a nest, how to feed the young and when to migrate; but biologists are still unable to explain many of their remarkable ways.

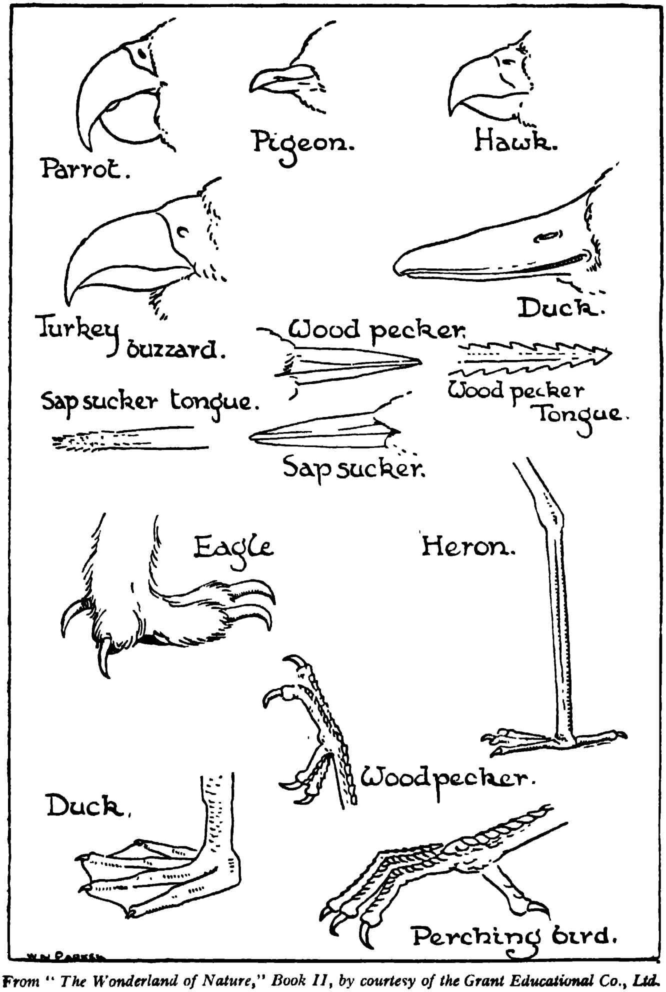
There are some birds, including the farmyard duck, cock and hen, which are unable to fly. These have lost their power of flight. The swan and vultures are the largest birds capable of flight, but the ostrich, which lives in Africa, is the largest of all living birds. This has very long legs and measures about seven feet high. The smallest bird is the little humming bird of America, which lives chiefly on the nectar obtained from flowers. There are many kinds of humming bird.

Songs of Birds

Many birds are able to produce sounds and each kind has its own particular song. The thrush, blackbird, nightingale, garden warbler, willow warbler, canary, robin, skylark, and many others sing rich, clear notes and their songs are among the greatest delights in Nature. Birds are able to produce these sounds by a special organ known as the *syrinx*, which is situated at the base of the windpipe.

Feet of Birds

The feet of birds are an indication of some of their habits. Some birds have feet formed for perching, others for swimming, wading or scratching. The sparrow has long claws which it uses for perching; the woodpecker has four claws, two pointing forward and two



From "The Wonderland of Nature," Book II, by courtesy of the Grant Educational Co., Ltd.

Fig. 80. Beaks and feet of birds

backward, suited for climbing; the duck and all water birds have webbed feet, their toes being joined by skin, which enables them to swim. The eagle and birds of prey have strong curved claws called talons, which they use for catching and tearing their victims (Fig. 80).

Beaks of Birds

The beaks of birds, too, indicate the kind of food they eat. The sparrow has a short, pointed beak for picking up seeds; the woodpecker has a long beak for boring insects out of the bark of trees; the duck has a broad, spoon-shaped bill edged with little teeth for scooping up the water and straining out the animals for food. The kingfisher has a long, thin beak for fishing in the water, while the eagle and owl have strong curved beaks for tearing their food to pieces.

Reproduction

Every bird starts its life from an egg which has been laid by the mother bird. Most birds build a nursery for their young, and some are remarkable architects and builders. Before building their nests, they have a definite period for courtship, known as the *mating season.* At this time, in the early spring, all wear their brightest colours and sing their sweetest songs. New feathers grow to replace the old ones which are faded and worn and gradually fall out. The change of coat is known as the *moult*, and during this stage which occurs in the later part of the summer, all birds are very unhappy and hide in quiet places. When mating is in progress it is necessary to prepare the home for the young. This is a remark-

Fig. 81. Marsh warbler feeding its young

able instinct and the wonderful co-operation of parents in providing shelter, food, protection and care for their young makes birds among the most delightful and charming of living creatures (Fig. 81).

The mother bird lays the eggs which have been fertilized by the male before they leave her body so that each egg contains the embryo of a young bird just as every seed contains the embryo of a young plant.

You will remember that reptiles leave their eggs to be hatched by the sun. Birds do not take that risk with their eggs. They build a nest where they feel that their eggs may be safe and the parents watch them and brood over them, that is, they cover them with their bodies and

wings to keep them at an even temperature until the young are hatched.

The time that a bird covers her eggs is known as the *incubation period*, and the length of this period varies with different birds. During this time, the embryo is developing into a chick and at the end of the period the young bird breaks through the shell and hatches as a nestling covered with down. As it leaves the shell it is fully formed and a miniature of its parents.

Observation

The hen's egg.

Apparatus. (1) A boiled egg; (2) a raw egg; a dish.

An ordinary hen's egg is typical of all birds' eggs. The egg has a particular shape, being broad at one end and pointed at the other. It is protected by a shell formed of a skin strengthened with calcium carbonate and is brittle and porous. Inside is a living germ which needs air to breathe, so the shell must allow air to pass in.

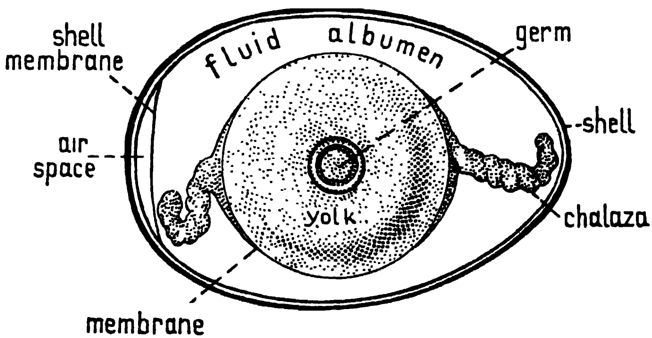


Fig. 82. Structure of a hen's egg

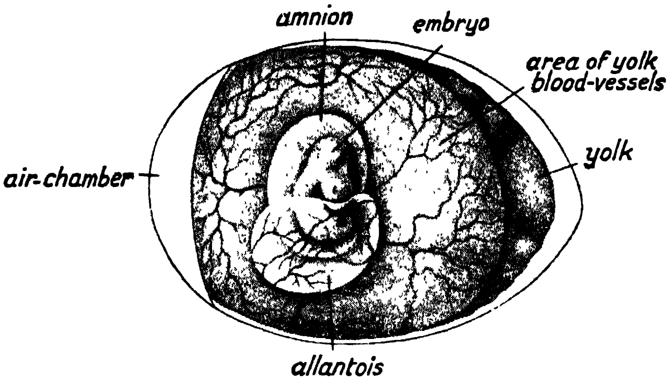


Fig. 83. A hen's egg after five days' incubation

If you break off the shell of the boiled egg you will notice two skins ; one is attached to the shell ; the other surrounds the white of the egg. These skins are close together, except at the broad end where they are separated by a small space containing air (Fig. 82).

If you break the raw egg carefully into a dish, the white appears as a clear, colourless liquid which surrounds the yellow yolk, and this also is protected by a skin. If you look carefully you will see that the yolk is balanced like a hammock between two twisted cords (each called a *chalaza* which act as buffers or shock absorbers, so that the yolk shall not be disturbed when the egg is moved).

If the egg has been fertilized, the tiny embryo will be seen at the top. It appears as a little dark speck of jelly, but it is a living cell, and, if the egg had been placed under suitable conditions, this cell would have developed into a chick.

By nature, a hen keeps her eggs at a warm temperature of about 100° F. by brooding over them. They can also be kept at this temperature in an incubator. Then the embryo develops (Fig. 83). The living cell at once begins to feed on the yolk and the white of the egg and starts to grow. The cell divides to form more cells, which in turn divide until the end of the incubation period, when the chick is quite formed and ready to hatch out. Soon after it leaves the shell, it is able to peck and find its own food.

QUESTIONS ON CHAPTER 29

1. In what ways are birds distinguished from all other animals?
2. Explain how the structure of birds enables them to fly in the air.
3. Compare the blood temperature of birds with that of other vertebrates.
4. Describe the size, shape and plumage of a pigeon.
5. Compare the limbs of a pigeon with those of any other vertebrate.
6. What kind of food does a pigeon eat? How is this food digested?
7. Write anything you know about migratory birds.
8. The feet of birds indicate something of the life they live. Explain this.
9. The beaks of birds indicate the kind of food they eat. Explain this.
10. What do you understand by "instincts"? Describe any instincts common to birds.
11. Draw and describe the inside of a bird's egg.

CHAPTER 30

SOME MAMMALS

MAMMALS form the most highly developed class of vertebrates. Generally these animals are *quadrupeds*, but there are a few exceptions. Man is a mammal and he is a *biped*, because he uses two legs only for walking. The bat, too, is a mammal, and it uses its fore-limbs as wings for flying; while in the whale, which is the largest mammal, the fore-limbs are modified into fins which it uses for swimming.

Although many quadrupeds have fore-limbs different from the hind-ones, in all cases the fingers and toes are protected by *nails* or *claws*.

Mammals are warm-blooded animals and most of them are covered with hair which keeps the body at an even temperature. Consequently, mammals can live in most parts of the world, for the covering of hair varies in accordance with the climate. Hair may be of fine texture and form fur; or it may be wavy as the wool of sheep; or stiff as the bristles of a pig; or the hairs may grow large and form protective spines as in the hedgehog and porcupine.

Unlike most other animals, the young of mammals are born alive and are nourished for some time after birth by milk which is secreted by the milk glands of the mother. Mammals are also distinguished by the possession of a highly-developed brain.

The class Mammalia is very large, and though certain characteristics are common to all, some mammals differ in many respects from others. They differ in their diet, and the kind of food which they eat is indicated by the shape of their head, jaws and teeth. Consequently, mammals may be classified according to their diet into those which are (*a*) *carnivorous*, or feed on the flesh of other animals; (*b*) *herbivorous* and live on vegetation; (*c*) *omnivorous* and feed on a mixed diet of flesh and vegetable food as do pigs, rats and human beings.

The majority of mammals live on land, yet among these there is a great variety in their habits. The mole lives in the soil; the sloth dwells among the trees; the bat is capable of flying through the air; and the whale lives permanently in the water, though it has to come up to the surface to breathe.

Apart from the great variety of habits, mammals also differ widely in their structure, development and intellect. Accordingly they are sub-divided, and those bearing similar features are grouped into orders and families.

Monotremes

Beginning with the least advanced in structure and intellect are the monotremes. These form a small group and consist of only two forms. They are curious animals and differ from all other mammals and from each other. The duck-billed platypus, or the duck-mole, is the name of one of them (Fig. 84).

This strange creature lives in Australia, and has a bill resembling that of a duck. The duck-mole has a peculiar way of producing its young. The female lays eggs with shells like those of birds, but when these are hatched, the

Mondiale

Fig. 84. A duck-billed platypus

young are fed with milk from the mother, like all other mammals.

The echidna or spiny ant-eater is perhaps the best-known species of the other family of this mammalian order. This animal is about the size of a hedgehog and not unlike that animal in appearance. It has a longer snout, which it uses for burrowing; but it is covered with spines and is capable of rolling itself up into a ball. It produces young in the same way as the duck-mole. This curious animal is found among the rocky and mountainous districts of New South Wales, Australia.

Marsupials

These animals have a pouch, or a kind of natural pocket, under their bodies. In this they protect their

young until they are able to feed and protect themselves (Fig. 85). Most marsupials, for example, the kangaroo, live in Australia. The kangaroo is a quadruped rather larger than a sheep, but it does not walk on its four legs. It travels by making a series of great leaps with its hind legs, which are long and very powerful. Its fore-limbs are short and used more like hands, especially in connection with the pouch and with feeding. It has a long, strong tail, which it uses as a support when sitting or resting.

Australian National Travel Association

Fig. 85. A kangaroo with young

When the kangaroo is born it is a very immature creature, about an inch and a half in length, blind, quite helpless, and without limbs. At once it is placed in the pouch, where it is nourished with its mother's milk. When its limbs are formed and it is sufficiently developed, it leaves the pouch, feeds on grass and lives independently like its mother, though for some months it still uses the pouch as a bed and refuge from enemies.

Fig. 86. A two-toed sloth

Edentata

These form another group of mammals found chiefly in Central and South America ; they are so named because most of them have no teeth (Fig. 86). They include the ant-eaters, sloths, and armadillos, but they are not all toothless.

CETACEANS

These are a family of mammals which live in the sea. They include whales and dolphins, and, although these animals possess all the general characteristics of other mammals, they differ so much from them in external form and in habits that they more closely

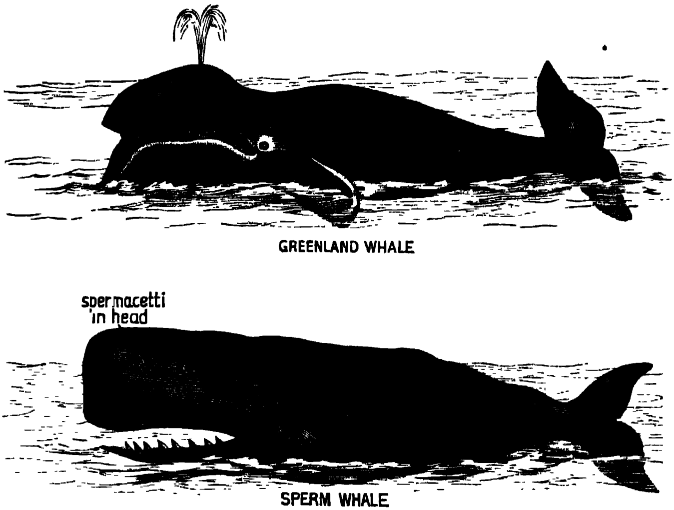


Fig. 87. Types of whale

resemble fish. Their fore-limbs are fin-like paddles and they have no developed hind-limbs as land animals have. The tail is fringed with a pair of flat, fleshy flukes shaped like those of mackerel, and some species also possess a dorsal fin (Fig. 87).

The whale is the largest animal in the world and some whales measure as much as sixty feet long. The animal

is covered with a smooth thick skin, but under this is a deep layer of fat, called *blubber*. This helps the whale to float and to keep the body at an even temperature.

The whale has a very large head, but its eyes and ears are comparatively small. Its nostrils, or blow holes for breathing, are on the top of its head. Though the whale lives entirely in water it does not, like a fish, take its oxygen from the water; but it draws air through its nostrils to its lungs as do other mammals. When it breathes it drives out the water which has entered its nostrils and this spouts into the air as from a fountain.

QUESTIONS ON CHAPTER 30

1. What features have mammals which distinguish them from all other animals?
2. Into what three groups are mammals classified by their diet?
3. Give a description of a duck-mole.
4. What are marsupials?
5. Describe a kangaroo. Where does it live and what does it eat?
6. In what ways do the animals forming the group Edentata differ from all others?
7. What features are common to all cetaceans? Name the chief members of this group of mammals.
8. Describe the shape and limbs of a whale.
9. How does a whale breathe?

CHAPTER 31

UNGULATA

All members of this group have their toes enclosed in hard, horny cases called *hoofs*. Actually the hoofs are very broad nails which grow across the ends and sides of the toes. The number of the toes varies in different members of this family, so for the purpose of study it is usual to arrange them as odd-toed and even-toed animals.

The Ungulata also are herbivorous animals and have broad molar teeth for grinding their vegetable food. These are a contrast to the teeth of carnivorous animals which have fangs for tearing the flesh off the bones of their prey. Their digestive organs are also different since they eat different kinds of food.

The Ungulata with even toes comprise the pig, cattle, antelope, deer and camel; and those with odd toes include the rhinoceros, tapir and horse. The elephant possesses five toes; but having a trunk and other distinctive features is usually classified alone.

The Elephant

The elephant stands as a giant among land animals. Some elephants are so large and heavy that they weigh as much as four or five tons. The elephant is a noble animal, and differs in several ways from all others. It is covered with a thick, greyish-brown skin. It has an enormous

E.N.A

Fig. 88. Indian elephant with young

head joined by a very short neck to its great massive body which is supported by strong legs (Fig. 88).

Its ivory tusks, which are really its two upper incisor teeth, also prevent it from grazing or from browsing on leaves of trees or shrubs. An upper lip of the common form, as in the horse or cow, would be of no use to the elephant. It needs this special type with which it smells and gathers its food and carries it to its mouth.

The elephant, because of its huge size and vegetarian

diet, requires food frequently and in large quantities. The *trunk*, or *proboscis*, is a very special organ which has many functions. It is really an extension of the nose and consists of a double tube six or eight feet long. At the end are the nostrils and the upper lip which is extremely sensitive and used as a finger-like feeler, so that the elephant can pick up very small articles. By means of its trunk the elephant feeds itself, snatching leaves, fruit, etc., from the trees ; it drinks by sucking its trunk full of water and squirting it into its mouth, and protects itself by using the trunk as a weapon ot offence against its enemies. It uses its trunk also as an arm and can skilfully uproot a tree, carry heavy logs, pick up a pin, throw a shower of water over an unfortunate offender or strike a deadly blow at an enemy.

The elephant possesses the senses of seeing, hearing, taste, smell and touch in great perfection. The eyes are very small, but quick and lively, and the two large drooping ears are alert to the sounds of the forest.

By nature, elephants like to live in herds and they inhabit the forests of tropical Asia and Africa ; but they have wandering habits and do not stay long in one place. They are fond of water and are excellent swimmers and so usually live in swampy regions.

QUESTIONS ON CHAPTER 31

1. What features in common have the animals forming the group ungulata?

2. How are these animals classified?

3. Give the names of three animals with (*a*) odd, (*b*) even toes.

4. Describe an elephant.

5. What is the elephant's trunk? What are its chief functions?

6. What are the elephant's tusks?

7. Describe the elephant's sense organs.

8. Where and how does the elephant live in its natural state?

CHAPTER 32

RUMINANTS

Animals which Chew the Cud

Ruminants are mammals which are cud-chewers and have a special arrangement for eating their food. They include the ox tribe and many of them are very useful to man (Fig. 89).

Instead of teeth in front of the upper jaw these animals

W S. Berridge

Fig. 89. A milch cow

have a hard pad or gum. Opposite this, in the lower jaw, are eight cutting teeth which, when the animal is feeding, press against the pad. They have also, on each side of both jaws, six molar teeth which are used for grinding their food.

Digestion. Ruminants possess a peculiar digestive system. When a cow feeds, it tears off the grass by twisting it with its tongue. This food passes directly into the stomach which has four compartments. It first passes into the largest, known as the *paunch*. From

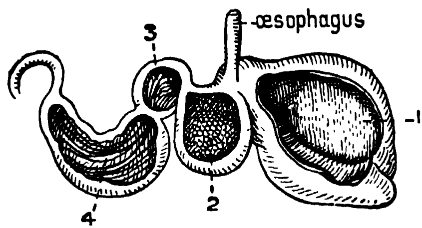


Fig. 90. Stomach of a ruminant

this it passes into the *honeycomb bag*, so called because the cells forming its lining, resemble honeycomb. In these cells the food is rolled into little balls called " cuds ", and returned to the mouth to be ground between the grinding teeth (Fig. 90).

When walking about the field the cow collects its grass, but when lying down it may be seen grinding these little balls and is said to be " chewing the cud ". When this is done the food is swallowed a second time and now passes into the third compartment called the *manyplies*, or manyfolds, because it is lined with many folds of skin. From this the food goes into the fourth compartment known as the *reed* or *rennet*. This is the real stomach, for in this the food is dissolved by digestive juices.

The cud-chewing animals have also characteristic feet. Each foot has two large toes enclosed in a horny case,

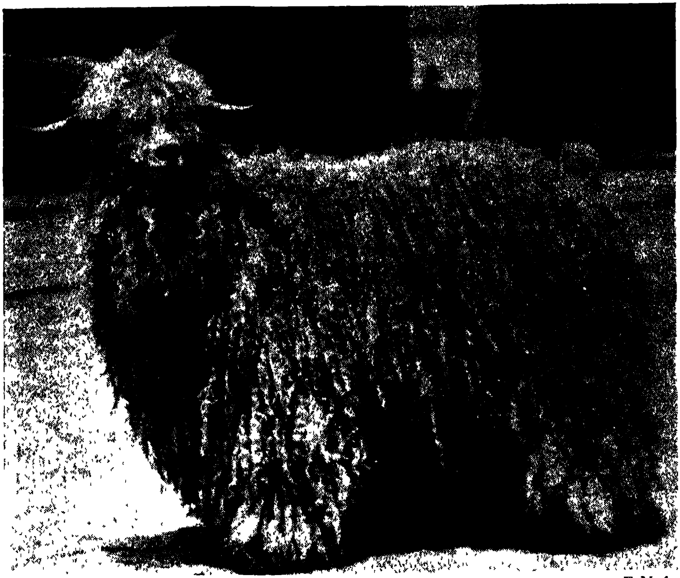

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Fig. 91. A young Angora goat. This specimen has never been clipped

but they fit so closely together that they appear as a single hoof that has been split or divided down the middle. For this reason ruminants are known as the animals with the cloven hoofs. Behind the hoofs are two small toes which do not touch the ground.

The Ox Tribe

There are many large animals belonging to the ox family. It includes the Brahmin bull in India, and the wild buffalo which lives in herds in the swamps of the Ganges. The yak of northern India and China is a relation and

the bison in America is another. This is a very powerful beast and wonderfully robust and massive in its structure. The musk ox also belongs to this group. This animal inhabits the American tundra and resembles a large sheep. It grows a thick woolly fleece which gives out a characteristic musky smell as a means of self-protection. All sheep and goats, too, are akin; they all have cloven hoofs. The angora goat, which lives in Asia Minor, has a lovely, long, white silky fleece which hangs in spiral ringlets (Fig. 91).

The little goat which inhabits the highlands of Tibet also has a very choice fleece. The ibex, too, is a very charming animal. It lives among the mountains of Europe and Asia.

E.N.A.

Fig. 92. A young gazelle photographed in Tunis

Antelopes are also ruminants. There are many kinds of them, and in one or more of their features they all resemble the ox, sheep and goat, thus showing their descent from the same far-off ancestors. Some species living in Africa are especially attractive with their striped bodies and long twisted horns.

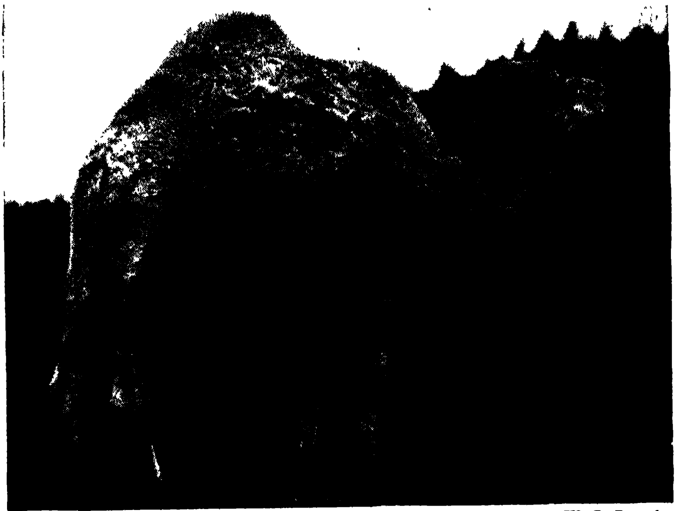
The gazelles which live in Africa and roam about in great herds are very alert and active (Fig. 92). The

springbok, its near relation, moves with great leaps and bounds as its name implies.

The giraffe is the tallest of all the antelopes and of all animals. It has long legs and a very long neck which enables it to eat the leaves from high branches. Its beautifully blotched skin, blending with the light and shade of its surroundings, protects it from its enemies (Fig. 93).


Fig. 93. Giraffe with young

The camel (Fig. 94) and the llama, its near relation, are most interesting animals. They are ruminants, but they differ from the others in many respects. The camel is wonderfully adapted for life in dry, arid deserts where it is destined to live. Its covering of long shaggy hair tones with the colour of the sand. Its head is long and its large eyes are protected from the glare of the sun by eyelids and long upper lashes. Its upper lip is cleft and mobile to enable it to bite off short twigs and plants, and its slit-like nostrils can be closed at will to keep out the sand. Its knees are protected with pads of skin on which it rests to receive its burden and the soles of its feet are provided



W. S. Berridge

Fig. 94. A camel

with cushions of skin which spread in width as the camel walks over the sand and prevent it from sinking in.

The hump is the prominent feature. This consists of a mass of fat reserved for time of need. When food is scarce the camel draws from this store and absorbs it into its system. The Arabian camel has one hump, the bactrian camel, a rarer species, has two.

The camel chews the cud, but its stomach differs from that of an ox in having only three compartments. The second compartment contains a water supply, which enables the camel to travel long journeys across the hot dry sand.

The dromedary also has one hump, but being lighter in build, it is capable of travelling more quickly.

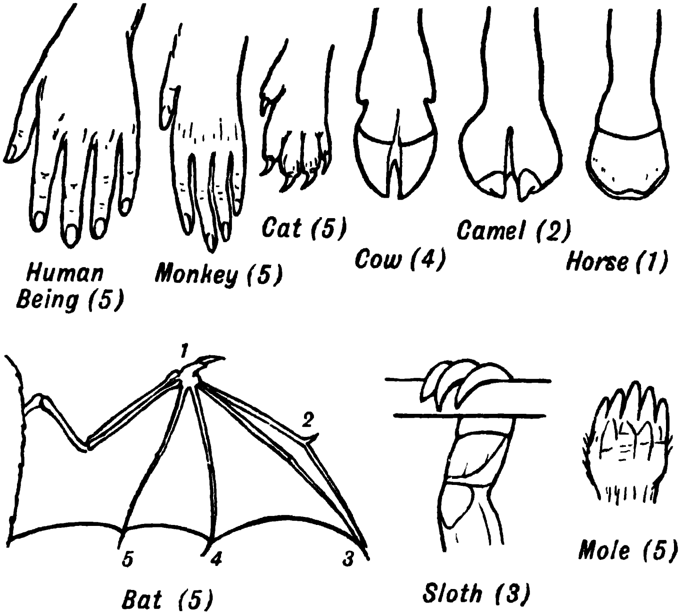


Fig. 95. Different types of extremities of fore-limbs in animals

The bactrian camel stores its fat in two humps. This animal inhabits the deserts of Persia and Central Asia and is becoming comparatively rare.

The llama closely resembles the camel, but being lighter in build, it travels at a greater pace. The llama lives on the slopes of the Andes and climbs with great agility. It is easily tamed and used as a beast of burden.

The horse, ass and zebra are animals with single toes and so form another group of Ungulata (Fig. 95).

QUESTIONS ON CHAPTER 32

1. How are ruminants distinguished from all other animals?

2. Describe how a cow eats and digests its food.

3. Describe the foot of an animal with cloven hoofs.

4. What do you know about the bison of America and the yak of India?

5. Give the names of six animals with cloven hoofs.

6. Write what you know about antelopes.

7. Describe the giraffe.

8. Show how a camel is suited to life in a desert.

9. In what way does the stomach of a camel differ from that of an ox?

10. What are the chief differences between (*a*) the Arabian camel, (*b*) the dromedary, and (*c*) the bactrian camel?

11. Where do these animals live: ibex, gazelle, llama, musk ox?

12. Why are the horse, ass and zebra placed in a different group from the ox and camel?

CHAPTER 33

RODENTS

The Gnawing Animals

The rodents are the gnawing animals. They are provided with broad, flat, chisel-shaped teeth set in front of both jaws and so are specially adapted for gnawing their food.

Unlike human teeth, those of rodents are constantly growing in the same way that human finger nails grow and so they never wear completely away.

Rodents have a peculiar mouth which assists them in their gnawing habits. The upper lip is divided down the middle and is known as a hare lip. This is an advantage for it can be turned out of the way when the animal is gnawing its food, and enables it to bite close to the ground.

Rodents are vegetarians and feed on grass, corn, and other vegetable food. They form a very large order, and comprise about one third of the Mammalia ; but for the purpose of study, biologists have divided them into two classes according to the number of their chisel teeth.

Some have only two or three of these special teeth in their upper jaw, and others have four such teeth. All rodents have two of them in the lower jaw.

The first group includes rats and mice, the latter being the smallest of all quadrupeds. There are several kinds of mice of which the smallest is the field mouse. This timid little creature lives in the corn fields and

Fig. 96. A harvest mouse

climbs the stems of wheat to eat the grains of corn (Fig. 96). It takes great care of its young and protects them in a nest which it weaves with narrow leaves of grass and fastens on the stems of corn where their food is near at hand.

The rat is its nearest relation. Rats like to inhabit cellars and underground sewers; but though they often live in filthy places, they are useful scavengers and they themselves have very clean habits.

The brown squirrel is one of the most beautiful rodents. This active little animal has a thick coat of reddish-brown fur and a long bushy tail which it carries gracefully curved over its back. It is a tree-dweller and leaps among

By courtesy of Canadian National Parks

Fig. 97. Grey Owl, the former Canadian Government Protector of Wild Life, feeding a young beaver

the branches and seldom comes to the ground. At the approach of winter it collects a store of nuts, acorns, corn, berries and other fruits which it hides ; then it makes a nest of moss, hay or wool in the fork of a tree where it hibernates until the spring. On fine warm days

it wakes up to have a meal from its store and then retires again.

The beaver is one of the largest rodents. In form it resembles a rabbit and is covered with a coat of beautiful, thick, soft fur. Its fore-limbs are short and have paws which it uses like hands. The hind-legs have feet with webbed toes for swimming, and its broad flat tail, covered with scales, serves as a powerful oar in the water (Fig. 97).

Beavers are very sociable animals and usually live in communities near water. They are clever little architects and builders and show remarkable intelligence in the construction of dams and bridges, building their houses and lodges near to one another. They cut down the trees and carry their building materials to the site for their homes. There they arrange the logs in position, then cement them with mud and stones and so make their dwellings secure.

They are easily tamed and become very friendly with those who try to understand their nature.

QUESTIONS ON CHAPTER 33

1. How are rodents distinguished from other animals?
2. How have rodents been classified by biologists?
3. Describe a field mouse or rat.
4. Write what you know about a squirrel.
5. Describe a beaver and its habits.

CHAPTER 34

CARNIVORA

Flesh-eaters

The carnivorous animals live entirely on the flesh of others. They are hunters and so are fierce, strong and good runners. Their senses of seeing, hearing and smelling are highly developed and generally they are provided with sharp teeth and claws for seizing and tearing their prey.

All these flesh-eating animals possess the same characteristics, but they differ in certain details, especially in the use of their feet; and so they, too, are divided into groups according to their manner of walking. Some walk on their toes, others on the soles of their feet. The dog family, which includes the wolf and hounds, and the cat family, comprising the lion, tiger, leopard and jaguar, are toe-walkers. There are many varieties, due to breeding, among domestic animals, such as dogs and cats. This is especially the case in the former; for example, terriers, retrievers, hounds, whippets and spaniels (Fig. 98). The bear and badger families belong to the group of sole-walkers. The weasel family, which includes the ferret, polecat and stoat, form a link between the toe-walkers and the sole-walkers.

The walrus and seal are also carnivorous animals, but they belong to another group.

Fig. 98. A spaniel dog
Compare this with other varieties of dog

The cat and all its wild relations, including the lion, tiger and leopard, are keen hunters. They all have padded paws for hunting stealthily, sharp retractile claws for seizing their prey and long canine teeth for tearing their victims to pieces. A study of the cat gives some indication of the structure and habits of its wild relations.

The lion is the largest and most formidable member of the cat tribe. A full grown lion stands about four feet high and measures about ten feet from the tip of its nose to the end of its tail, which is approximately three feet long. Its covering of tawny or light brown hair blends with the colour of the plains and brushwood where it makes its home. The male lion has a long, brown,

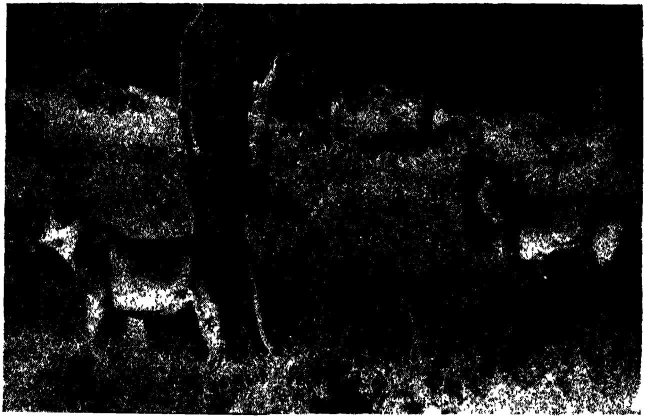


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Fig. 99. A lion and lioness wandering in the Transvaal, Africa

shaggy mane along the back of the neck and shoulders, and a tuft of long hair at the end of the smooth tail. The female, or lioness, is smaller than the male and is not so ornamented as he is (Fig. 99).

The lion is a solitary animal and usually sleeps in his lair during the day ; but as night sets in he begins to prowl in search of food. If he is hungry, the large herbivorous animals, the horse, ox, or other large beasts of the forest, may be attacked by him. Unless he is hungry he is too lazy to hunt, and then he does not kill other animals unless they attack him.

The tiger more closely resembles the cat. It is smaller than the lion but is fiercer, more cruel and blood-thirsty. Its coat is tawny and beautifully marked with stripes of black so as to harmonize with the trees and shadows of

Fox Photos

Fig. 100. A brown bear carrying its young

the jungle. The jaguar and leopard are also beautifully marked in yellow and black. Most bears, on the other hand, are usually all brown, or black or white (Fig. 100).

QUESTIONS ON CHAPTER 34

1. What are the chief characteristics of the carnivorous animals? Name six which belong to this group.
2. How is this group of animals subdivided?
3. Give the names of two animals which are (*a*) toe walkers, (*b*) sole walkers.
4. What are the characteristics of the cat tribe?
5. Describe a lion and lioness.

6. Describe a tiger. Why has it such beautiful markings?

7. From a study of Carnivora explain how they themselves are protected by nature from their enemies.

8. Describe the feet of the cat tribe.

CHAPTER 35

INSECTIVORA AND CHIROPTERA

INSECTIVORA

THE Insectivora are a small group of mammals. Many have retiring habits and live underground in burrows, while a few are aquatic. The mole, shrew and hedgehog belong to this order. As a rule, they all feed on insects such as beetles and others which live in the soil. Some, however, are fond of plant food ; others like to eat worms and slugs ; while those in water feed on marine animals.

Generally Insectivora have limbs adapted for walking and also for digging the soil. The feet have five toes ending in curved claws and are used as tools for making their burrows. The nose is long and suited for burrowing, and the jaws have teeth which are used for crushing beetles and other insects.

The mole is perhaps the best known member of this group (Fig. 101). It is a native of this country so that perhaps one may be procured for observation. The chains of little mounds above its burrows are very common in our grass fields.

The mole measures about six inches in length and its cylindrical body is covered with a velvety coat of soft glossy, brownish-black fur. The head is shaped like a wedge and admirably adapted to its burrowing habits. Its snout is long and pointed and its small eyes are almost


W. S. Berridge

Fig. 101. A mole

hidden in its fur. It has a very keen sense of smell and can hear remarkably well though it has no external ears.

The fore-limbs are very short and have broad flesh-coloured flat hands armed with five strong claws (Fig. 95). The hands are used as spades and, with the help of its long pointed nose, the mole makes its burrows very quickly.

The mole feeds entirely on animal food which it finds at night. Its diet consists of earthworms, grubs, insects, mice, birds, frogs and even other moles which trespass in the burrows.

Home and fortress. When the mole is making its home, the earth which it throws out from the burrows forms the little mounds or mole-hills so common in grass fields. Beneath one of these mounds is a circular chamber

Fig. 102. Section of a mole's nest W. S Berridge

where the mole retreats for rest and safety. From this fortress, roads run underground in every direction. Some lead to the store rooms; some to the nursery, where a nest is made of dry grass and leaves to keep the young ones warm (Fig. 102); others are used as dormitories.

The Chiroptera

The Chiroptera form another group of curious mammals. These animals include the bat family, which are remarkable because of their ability to fly.

The bat resembles a mouse in size, form and colour; but it is covered with soft brown hair and is really more like a mole, to which it is more closely related (Fig. 103).

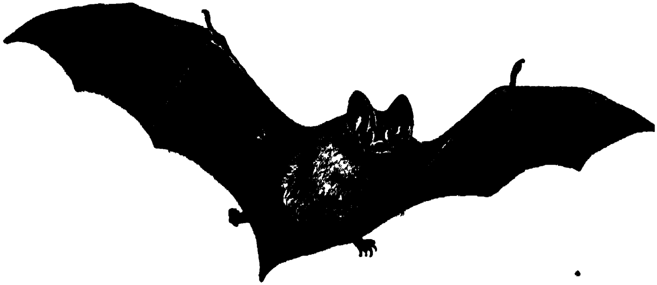


Fig. 103. A bat

The fore-limbs or arms are modified as wings. They are bent at the elbows, and the four very long fingers are connected by a delicate skin which joins them to the sides of the body to form wings (Fig. 95). The thumbs are free and each has a claw at the end. The breast bone projects and forms a ridge, or keel, corresponding to that in birds, and to this bone are attached the strong muscles needed for flight. When flying, the bat spreads its wings and uses them in the same way as a bird; at other times it folds them close to the body.

The hind-legs have five toes, each armed with a long curved claw. The head is mouse-like, but the ears are very large and curiously formed. The eyes are small and bright and the comparatively large mouth is furnished with very sharp teeth. Some bats have peculiar nostrils, surrounded by delicate frilly skin, which not only aid the sense of smell but probably are organs sensitive to touch.

Bats are especially adapted by nature to an aerial life. They are able also to crawl along the ground and, when at rest, they usually hang by their claws with their heads downwards.

Generally bats live on animal food, though they often eat fruit as well. Usually they sleep during the day, because they are dazzled and cannot see well by daylight. In twilight and at night they can see very well, so then they come out in search of insects and any other food.

These little animals possess a very keen sense of touch; and it is believed that by the extremely delicate membrane in the wings they may even feel the difference in the pressure of air, and so are able to avoid obstacles in their way. They fly very swiftly and seem to be aware of the presence of objects and, though it may be dark, they avoid touching them.

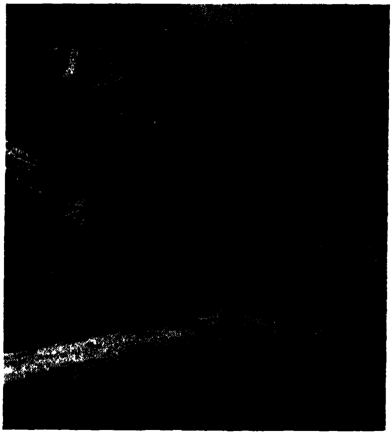
QUESTIONS ON CHAPTER 35

1. Give the names of three animals belonging to the group Insectivora. What features have they in common?
2. Describe the limbs of these animals.
3. Describe the external appearance of a mole.
4. What features has a mole which make it suited to its burrowing habits and life underground?
5. Describe the home of a mole.
6. What group of animals includes the bat family?
7. Give a general description of a bat.
8. Describe the wings of a bat and show how they correspond in structure to the fore-limbs of other higher vertebrates.
9. Describe the sense organs of a bat. Explain why some scientists believe bats are able to avoid objects when flying in the dark.
10. What is the food of bats and how do they procure it?

CHAPTER 36

PRIMATES

PRIMATES form the highest order of mammals, and comprise lemurs, tarsiers, monkeys, apes and man. All are primarily arboreal animals with hands and feet adapted for climbing. Their limbs are relatively long and slender, and the upper arm and thigh are free and not enclosed in the skin of the body, as are those of the cat, cow, bear and most other mammals. The fingers and toes are provided each with a nail, and the big toe of the hind-foot to some extent can be used as a thumb, so that many of this order can grasp branches of trees with their feet. The fore-limbs can be used for climbing, and also as hands for obtaining food and for grasping objects.



F. W. Bond

Fig. 104. A lemur

Lemurs

The lower primates consist of lemurs and tarsiers, which are not so advanced in development as monkeys and anthropoid apes.

Lemurs form a link between monkeys and other mammals (Fig. 104). They are about the size of cats and are forest dwellers. They have long, slim, furry bodies with a long, bushy tail, and slender limbs with hands and feet which they use for grasping, as they climb and leap among the trees.

The chief home of the lemurs is Madagascar, where they live in troops in the forests. This island has been their headquarters for a very long time, but some are also found in the island of Celebes and in tropical forests of Asia and Africa.

Monkeys

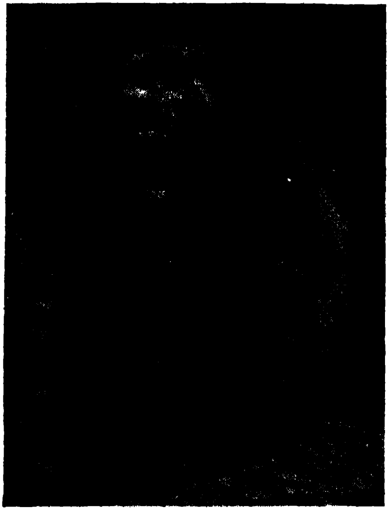
There are many kinds of monkeys (Fig. 105). They vary in size, colour and other details, but with very few exceptions all monkeys have tails. Some kinds have a very long tail which can be twisted round a branch and used as a fifth hand for swinging among the trees. Many monkeys also have little pouches, like bags, inside their cheeks, which they use as natural pockets for storing nuts and other food until wanted.

Monkeys are natives of the hotter parts of Asia, Africa and America, but they form two distinct groups. Those of the Old World have a long narrow nose with the nostrils placed close together; and those of the New World have a broad and flat nose with nostrils wide apart.

The African monkeys have cheek pouches, while most of the American species have long *prehensile* or grasping tails.

Though there are many monkeys in India, the chief home of this tribe is South America, where a traveller says that some of the great forests are filled with the cries, yells and roarings by day and by night of countless troops of these restless creatures. They include all sizes from the large howlers to the tiny marmosets.

The howlers are large, stout-bodied monkeys with bearded faces and very strong, powerful grasping tails.



F W. Bond

Fig. 105. A baboon, a north-east African monkey

The marmoset is the smallest member of the monkey tribe. This little creature is not much larger than a squirrel, and has a head very much like that of a fox. It is covered with long silky hair, and has a very long bushy tail.

Anthropoid Apes

The anthropoid apes are the animals most nearly akin to man. This family consists of only four members, namely, the gibbon, orang-utan, chimpanzee and gorilla.

The gibbons have slender bodies with very long fore-limbs and are covered with brownish-black, woolly hair. They stand about three feet high and their arms are so long that, when the body is erect, the fingers can touch the soles of their feet. The palms of their hands and the soles of their feet are not covered with hair, and they are tail-less. Gibbons are tree dwellers and swing very quickly from bough to bough by their long arms and hook-like fingers. They display wonderful agility and carry their food in their feet. They rarely come down to the ground of their own accord; but, when obliged to do so, they run along almost erect, holding their arms out as balancers.

E.N.A.

Fig. 106. An orang-utan

These animals are vegetarians and by nature they are gentle and rather melancholy. They are found in the Malay Peninsula, East Indian Islands, and other parts of Asia, as well as in south-east Africa.

The orang-utans are larger animals than the gibbons and when full grown often reach a height of five feet. They are covered with reddish-brown hair and have long

arms and hands but comparatively short legs. These animals inhabit the wild forests in the swampy parts of the Dutch East Indies and Borneo. They are tree dwellers and construct platforms in the trees where they live alone or in families. They feed on fruits and other products of the forest and rarely descend to the ground (Fig. 106).

The chimpanzee resembles more closely the human form. The adult is almost as tall as a man and is covered with blackish-brown, coarse hair, except the face, hands and feet which are bare. On the sides of the head the hair is long and hangs down like whiskers (Fig. 107).

E.N.A.

Fig. 107. A chimpanzee

The arms are much shorter and more human in form than those of the gibbon or orang, but they are longer than the hind limbs and reach down to the knees when the animal stands erect. The hands nearly resemble those of human beings, but when walking the chimpanzee rests upon the knuckles and not the palms.

The face of this ape is brown and the arched brow overhangs the small, alert eyes. The lips are very thick, and the ears, shaped nearly like those of man, are very large.

Chimpanzees live chiefly in the African forests away from human settlements. They are fond of company and usually live among trees, and some make little huts for safety to protect themselves from the weather. They feed on fruit, terminal buds of the cabbage palm, and other vegetable food.

E.N.A.

Fig. 108. A gorilla from the Belgian Congo. This specimen weighed 450 lb. and was 5 ft. 8 in. high

The gorillas are the largest of the anthropoid apes, and the strongest and fiercest member of the monkey tribe. Some of these animals reach more than five feet in height, measure sixty inches round the chest and weigh about five hundred pounds. As a rule they move about on all fours and run at a great speed. Their fore-limbs are much larger than the hind ones. Their fingers are short and less adapted for climbing than those of their near relations, and their feet more closely resemble those of human beings than do those of other primates, though they turn inwards when walking. The teeth in number and arrangement resemble

those of man ; the blood too of this ape is identical with that of man, and both are susceptible to diseases from which other animals are immune. In fact, in form and intelligence, the gorilla, the largest of the man-like apes, is the beast considered to be most nearly akin to man (Fig. 108).

There are, however, various ways in which man differs from this ape. Both gorilla and chimpanzee have thirteen pairs of ribs, one more pair than in man ; and there are differences in the proportion of certain parts, particularly in the comparative length of the fore-limbs and dimensions of the skull.

Man also differs from the gorilla in that he walks erect on two legs and that he has a brain three times as large. Moreover, man is distinguished from all other creatures by his superior intellect and his ability to store knowledge and to reason, which makes him responsible for his actions.

QUESTIONS ON CHAPTER 36

1. What animals belong to the order Primates?
2. Why are Primates the most highly developed mammals?
3. Describe a lemur. How do lemurs form a link between monkeys and other mammals?
4. What are the four members of the anthropoid apes?
5. Describe a gibbon. Where does it live and what kind of food does it eat?
6. In what ways do orang-utans differ from gibbons? Where is the natural home of the former?

7. Why is the gorilla the beast considered to be most nearly akin to man?

8. What are the main differences between this man-like ape and man?

9. In which parts of the world are gorillas found? What kind of food do they eat?

10. In what respects is man superior to all other forms of life on the earth?

CHAPTER 37

THE HUMAN BEING

THE SKELETON

MAN, like all the vertebrate animals, possesses a backbone and skeleton of bone. In structure all mammals follow the same general plan, and consist of a trunk to which are attached the head and limbs.

The human body is composed of cells. These are of various kinds and are grouped together to form tissue, that is, muscle, nerves, bones, etc., according to their purpose and function. One type of cell forms bone, another forms muscle, another nerve. Although there are so many different kinds of cells and tissue, when analysed chemically they are found to consist of the same substance as those forming the cells of other animals and plants. Nearly all the fluids and soft parts of the human body consist of carbon, hydrogen, oxygen and nitrogen. These elements, you will remember, form the living substance protoplasm.

BONES

The hard parts of the bones consist of mineral compounds, mainly phosphate and carbonate of lime.

Experiments

1. To remove the hard substances from bone

Apparatus. Beaker, rabbit bone, hydrochloric acid.

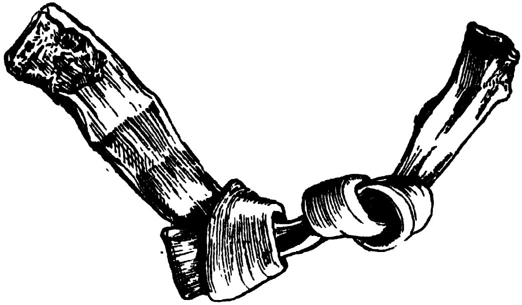


Fig. 109. A human rib tied in knots after the mineral matter had been removed by acid

Place a bone in dilute hydrochloric acid prepared from one part of acid and six of water, and leave for a few days.

Result. All the phosphate and carbonate of lime will be removed, though the bone will retain its shape. It will now be comparatively soft, so that it may be bent and twisted without breaking (Fig. 109).

2. To remove the soft or cartilaginous portion from a bone

By means of tongs hold a rabbit bone in a Bunsen flame for some time.

Result. The bone still retains its shape, but the cartilaginous portion will be gone. The bone is now brittle and can be broken to pieces easily.

Most of the parts in the structure of the human body have their counterparts in those of the higher animals, so

that if you examine the body of a rabbit you will better understand the anatomy of man.

The human skeleton consists of 208 bones of various shapes and sizes (Fig. 110). These hold up the fleshy parts and protect some of the delicate organs. Most of the bones are hollow tubes, strong but light in weight, and are similar in their chemical composition. The outside of bones consists of a hard substance formed from mineral matter, which gives them strength; and the inside usually contains a fatty substance, called *marrow*, for making blood. The flat bones, such as those of the skull, have very little marrow.

Some of the bones are fixed, but most of them are movable. These are jointed together in such a way that the ends can move one upon another. To give them smooth and easy movement, the ends of some bones are covered with a yielding cushion-like tissue called *cartilage*. Between the ends of the bones is a space filled with fluid which oils the joints and makes them move easily.

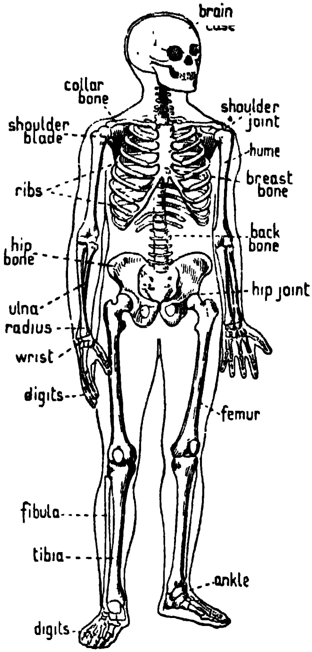


Fig. 110. The human skeleton

For the purpose of study the bones may be divided into the following groups :

(1) The head consisting of 30 bones.
(2) The body consisting of 54 bones.
(3) The upper limbs consisting of 64 bones.
(4) The lower limbs consisting of 60 bones.

1. Bones forming the head

The bones of the head consist of the skull, ears and face. The skull has eight bones which are dovetailed together in curious lines called *sutures*, so that they may not easily slip out of place. These zigzag joints can be seen easily in the skull of a rabbit. In early life these bones have a space between them to allow room for growth ; but as the individual grows older the bones unite firmly together. Each of the ears has four small bones arranged so as to aid the sense of hearing. The face has fourteen bones, and all are fixed, except the lower jaw which can be moved to open the mouth (Fig. 111).

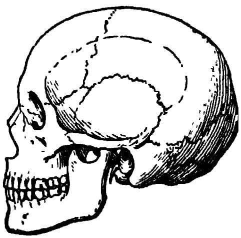


Fig. 111. The human skull

2. Bones of the body

The *backbone* or *vertebral column* consists of a long chain of thirty-three small bones called *vertebrae*. These bones are grouped and linked together in such a way that they form a long tube, which runs from the base of the skull to the bottom of the trunk and encloses the spinal cord.

The vertebrae are grouped and named as follows :

(*a*) The *cervical vertebrae* are at the top and form the neck. There are seven of them. The first, which supports the skull, is called the *atlas* and allows the head to nod. The second is called the *axis*, on which the head turns from side to side.

(*b*) The *dorsal* or *thoracic vertebrae* are the next twelve bones. To each of these is attached a pair of ribs.

(*c*) The *lumbar* or *loin vertebrae* consist of five larger bones which lie behind the abdomen.

(*d*) The *sacrum* is formed of the next five bones. These are united together and form the back of the pelvis.

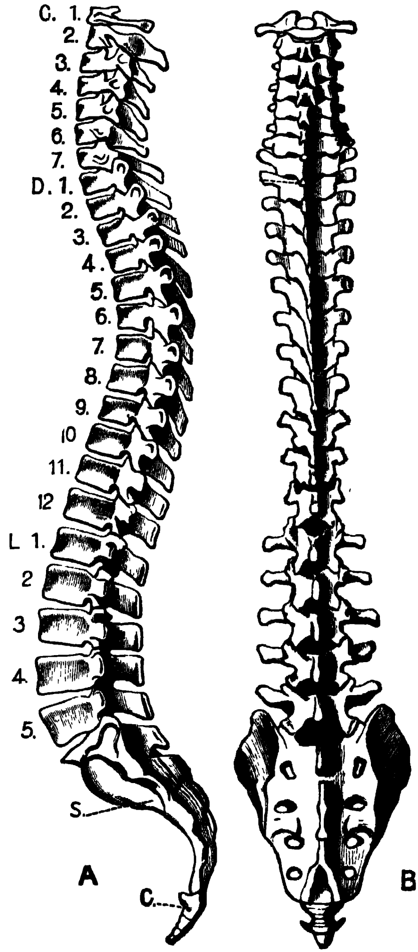


Fig. 112. Bones of the vertebral column. *A*, side view; *B*, back view; *C* 1-7, vertebrae of the neck; *s*, sacrum; *c*, coccyx

(*e*) The *coccyx* consists of the four

small bones at the bottom of the spine. In most other mammals the coccyx forms the tail (Fig. 112).

Each vertebra consists of a bone somewhat the shape of a pill box, with small projecting bones known as *transverse* and *spinous processes*. A hole passing through each forms the spinal canal and contains the spinal cord. Pads of *gristle* separate one vertebra from the next, acting as shock absorbers; and bands of tough fibres called *ligaments* bind the bones together so as to make the whole backbone flexible.

The *thorax*, or *chest*, is a dome-shaped cavity. This is formed by the dorsal vertebrae behind, from which the ribs extend round the sides and join the *breast-bone*, or *sternum*, in front. Above the thorax is the neck and below is the muscular partition called the *diaphragm*. This separates the thorax from the abdomen.

The *ribs* consist of twelve pairs of curved bones. They are connected at the back with the twelve dorsal vertebrae. The upper seven pairs are joined to the sternum in front; the next three pairs are united together and are then joined to the breast-bone by cartilage. The lowest two pairs are short, with their front ends free, and are known as *floating ribs*.

The thorax is really a bony cage which encloses and protects important organs—the heart, two lungs and the gullet down which food passes to the stomach.

The *shoulder girdle*. This is formed by two collar-bones, called *clavicles*, and two *shoulder-blades*. The rabbit has these bones similar in shape and arrangement. The collar-bones are long and slightly curved and are fastened at one end to the breast-bone, at the other end to the shoulder-blade.

The shoulder-blades are flat triangular bones and lie upon the upper part of the back forming the shoulders.

3. The upper limbs.

These consist of the *humerus*, or *upper arm*, the *lower arm*, the *wrist* and the *hand*. The humerus is a long bone which reaches from the shoulder to the elbow. At the shoulder it makes a ball-and-socket joint (see p. 252). This end of the humerus is round and fits into the socket of the shoulder-blade. At the elbow it forms a hinge joint with the lower arm. This part is formed by two bones called the *radius* and the *ulna*.

The wrist, or *carpus*, is formed by eight small bones arranged in two rows of four. The palm of the hand consists of five bones reaching from the wrist to the knuckles. These are called *metacarpal* bones. Each of the fingers has three bones, or *phalanges*, but the thumb has only two.

Fig. 113. Upper end of thigh-bone showing ball-and-socket joint

4. The lower limbs

The *hip girdle*, or *pelvis*, is a solid basin-like ring of bone which protects some of the lower abdominal organs. It is formed by two hip-bones joined to the sacrum. Each hip-bone is hollowed out to form a socket and receives the ball end of the thigh-bone (Fig. 113).

The leg bones correspond to those of the arms. They

consist of the *thigh-bone* or *femur*, the *lower leg bones*, the *knee cap*, the *ankle* and *feet bones*.

The thigh-bone is the largest bone in the body. The large round head is smooth and forms a ball-and-socket joint with the hip, and the lower end is joined at the knee to the lower leg bones.

The knee cap, called the *patella*, is a thick bone placed on the front of the knee joint. It is connected by muscles to the upper and the lower leg bones and is used in raising the leg. The lower leg has two bones; the larger one, or *tibia*, is the shin bone and the smaller one is called the *fibula*. These are joined at the ankle with the bones of the foot.

The ankle, or *tarsus*, is made up of seven small bones. The largest one forms the ankle and all are bound together like those of the wrist. The instep, or *metatarsus*, has five bones and corresponds to the palm of the hand. The tarsus and metatarsus together form the arch of the foot. The toes, or *phalanges*. consist of fourteen small bones. Each toe has three, except the big toe, which corresponds to the thumb and has only two.

Joints

Many bones are jointed together, so that they are movable. They are joined in different ways so as to allow for every variety of movement. The chief types are known as: (1) a *ball and socket*; (2) a *hinge joint*; (3) a *gliding joint*.

A ball-and-socket joint allows the limbs to move in many directions. The shoulder and hip joints are this type (Fig. 113). A hinge joint allows movement in one plane only. The knee and elbow have hinge joints.

Gliding joints allow only a small amount of movement. The bones of the ankle and wrist have this form of joint.

The joints are lubricated to make them move freely. The ends of the bones are held together by fibrous bands or ligaments, from which oozes a yellow fluid and this oils the joints.

QUESTIONS ON CHAPTER 37

1. What are the chemical substances of which the (*a*) soft, (*b*) hard parts of the human body are composed?

2. Describe two experiments to show how the hard and soft substances of a rabbit bone may be removed.

3. How many bones are there in the human skeleton? Name the four groups into which they are divided for the purpose of study.

4. Name the bones forming the head.

5. How many bones form the backbone? Give the names of the groups into which they are divided for the purpose of study.

6. Describe the bones forming the chest or thorax.

7. How many ribs are there in the human body? How are they arranged?

8. Describe the bones forming the upper limbs.

9. Name the bones forming the lower limbs.

10. How many bones form the wrist and hand? How are they arranged?

11. How many bones form the ankle and foot? How are they arranged?

12. How are the bones forming the human skeleton joined together? Give one example of each of the three kinds of joints.

CHAPTER 38

THE HUMAN BEING (*continued*)

MUSCLES AND RESPIRATION

THE muscles are the red, fleshy parts of an animal's body and form the lean meat. They are composed of bundles of fibres and have wonderful strength, for it is by these

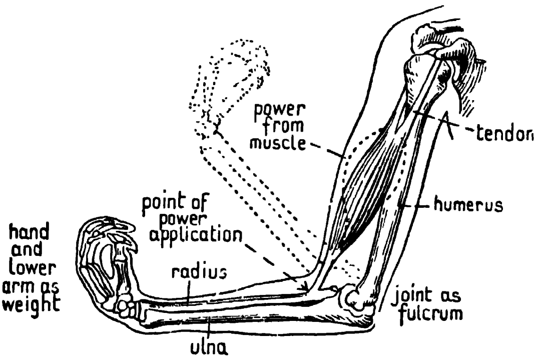


Fig. 114. The human arm as a lever

that the movable bones are worked. Towards the ends of the muscles the fibres become narrow and white like a cord and are very strong. These are called *tendons* and they fasten the muscles to the bones.

The action of the muscles can be observed by using the big one in your arm. Many of them shorten and expand as required, at the will of the individual. These

contractions cause them to act as pulleys and to move the bones in the directions desired (Fig. 114). If you stretch your left arm and hold the upper part with your right hand and then gradually bend your arm, you will notice that the upper arm gets thicker. The muscles of the upper arms are known as *biceps*. One tendon of the biceps is joined to the shoulder girdle, and the other to the forearm. When you wish to bend your arm, the muscle contracts in the middle, which makes it shorter and so draws up the forearm.

The muscles of the body are of various sizes. Each one is attached to a bone, but the largest and strongest are those developed on the arm (Fig. 115) and leg bones, where most power is required for movement. The muscles which cause various movements on the head and face are shown in Fig. 116.

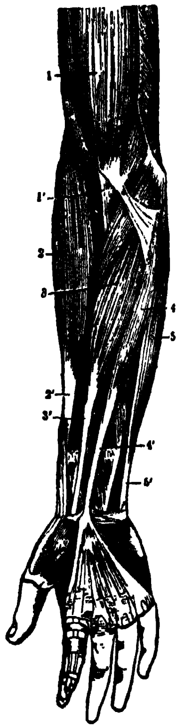


Fig. 115. Muscles of the arm (front view). 1, 2, 3, 4, 5—muscles. 1′, 2′, 3′, 4′, 5′—tendons

Kinds of Muscles

There are two kinds of muscles. Those which are under the control of our wills are known as *voluntary*; the others, which work by themselves, are *involuntary*. If we wish to raise a hand, the brain, connected by a nerve to the hand,

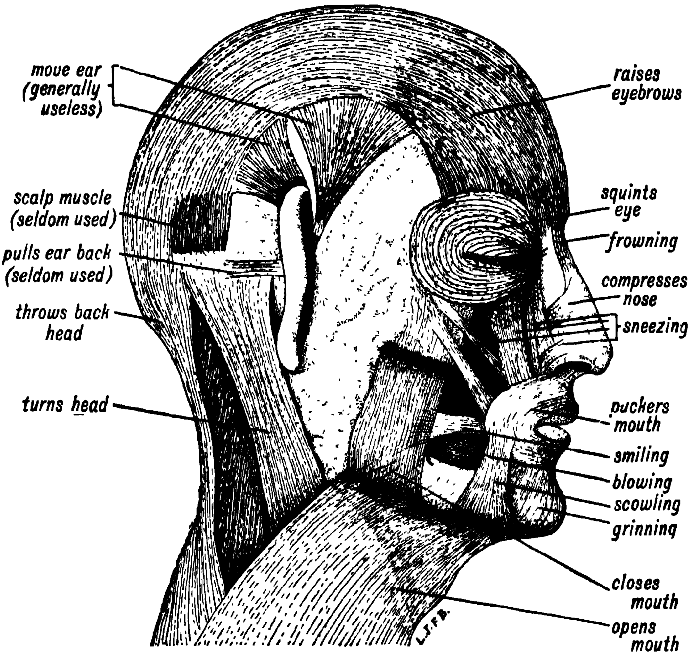


Fig. 116. Muscles of the face

enables us to do so. If the nerve were injured, the hand could not move by itself. All muscles of the limbs, neck and face are voluntary, and act by order of the brain.

Involuntary muscles are not under the influence of the will and so we are not able to control them. These work most of the internal organs and are found in the heart, walls of the intestines and stomach. The involuntary muscles work by day and night, whether we are awake or asleep. The heart muscle is a specialized type and is controlled by special nerves.

Organs

You will remember that an insect has three distinct parts, namely the head, the thorax and the abdomen. These regions in a mammal are not so clearly defined, yet the head forms a definite part; but the body cavity, though externally it appears as only one division, is actually divided into an upper and a lower compartment by a muscular partition, thus forming the chest and abdomen.

The chest, or thorax, contains the heart, two lungs, and the upper part of the digestive tract. The abdomen contains the stomach, liver, intestines, pancreas, two kidneys, bladder and reproductive organs.

The Lungs

Breathing. The lungs are the organs concerned with breathing. They are conical in shape, the base resting on the diaphragm of the thorax and the apex behind the collar bone. The right lung is divided into three lobes and the left into two (Fig. 117).

Respiration, in animal life, is a slow burning process. Just as in other cases of burning, oxygen is needed to keep it going, and during the process heat and energy are given out, while carbon dioxide is produced.

In mammals, the supply of oxygen is taken in through the nostrils and passes down the wind pipe, called also the *trachea*, and through the *bronchial* tubes into the lungs. At the entrance of each nostril is a number of stiff hairs which keep out particles of dust. Beyond these the air passage is covered with a warm, sticky fluid called *mucus*.

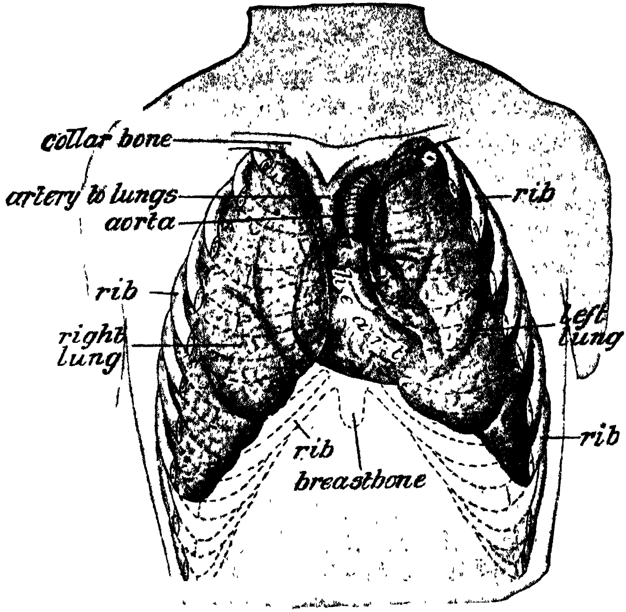


Fig. 117. The heart and lungs in the thorax

This warms and moistens the air as it passes in, and extracts smaller particles of dust and bacteria.

The air then passes through the *larynx*, which is the organ for producing the voice, and down the trachea into the chest. Here the pipe divides into two parts called *bronchi*. These divide and subdivide, until they become a mass of minute air tubes. Each has a little bladder-like expansion at the end and air spaces between them, so that the lungs resemble a very fine sponge. The lungs are supplied with numerous blood

vessels and protected by a smooth membrane called the *pleura.*

When the air reaches the lungs the oxygen passes through the thin walls of the air spaces into the blood, which becomes bright red and is then called *arterial blood.* This air is carried in the stream through the arteries to all parts of the body. At the same time, carbon dioxide is collected by the blood from every part of the body and is carried through the veins to the lungs. The blood which contains this gas becomes deep red and is called *venous blood.* In the lungs the carbon dioxide is given up, passes into the air spaces and is breathed out.

The act of breathing in air is called *inspiration*, and that of breathing out is called *expiration.* A healthy person makes 15-18 inspirations and expirations each minute.

During inspiration the muscles expand and force the ribs outwards; at the same time the diaphragm sinks, so that the size of the cavity in which the lungs are contained is increased. The air is thus drawn into the lungs. During expiration the muscles and the diaphragm relax, the cavity decreases in volume and the air is forced out of the lungs.

QUESTIONS ON CHAPTER 38

1. What are muscles? Explain how they work. What is necessary to keep them healthy?

2. Give the names of the two kinds of muscles. Explain how they are used or controlled.

3. Name the chief parts and organs of the human body.

4. Describe the lungs and the process of respiration.

5. Explain the following : tendons, biceps.

6. Describe the air passage from the nostrils to the lungs.

7. What is the pleura?

8. Explain the action and rate of breathing by a healthy person.

9. What are the following : trachea, bronchi, and diaphragm?

CHAPTER 39

THE HUMAN BEING (*continued*)

THE HEART AND BLOOD

THE blood of mammals is a red liquid and flows round the body in pipes, or blood vessels, called *arteries* and *veins*. The heart is the organ which drives it through the pipes and it never stops pumping from birth until death.

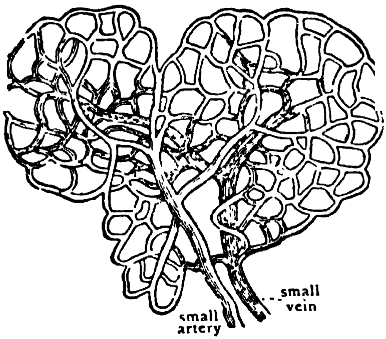


Fig. 118. Blood capillaries

The arteries are the tubes which convey the pure blood away from the heart to the organs and tissues of the body. The veins are vessels which lead the impure blood to the heart. The arteries leave the heart as big tubes, but these branch to all parts of the body and divide up into tiny hair-like tubes called *capillaries* (Fig. 118). The other ends of the capillaries collect up blood containing impurities which passes into the veins and flows back to the heart. This is venous blood.

The Heart

The heart is a muscular organ which works like a pump. If you press your hand to the left of your chest you will feel this pump at work.

The human heart is pear-shaped and in size corresponds to the clenched fist of the person to whom it belongs. It lies obliquely in the chest behind the breast-bone and

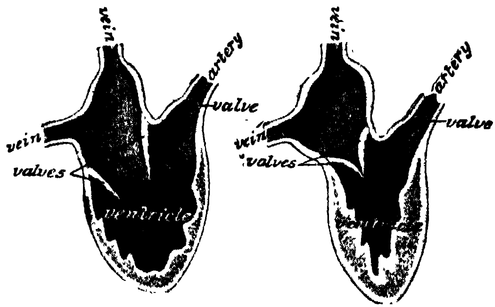


Fig. 119. The human heart in section

Left, the ventricle is dilated and receiving blood from the auricle; right, the ventricle is contracting and forcing its contents into the artery

between the right and left lung. The apex points slightly forward and to the left. It is enclosed in a fibrous bag called the *pericardium*. This consists of two layers separated by a small quantity of fluid which allows the heart to work freely.

The heart is very muscular and its fibres are so interwoven that it is very strong. We have no control over these muscles, but they never cease to contract and expand while we are alive.

Observation

If you examine the heart of a sheep it will help you to understand the structure of the human heart. It will be noticed that the heart is divided by a partition into a right and left part. The right part sends the impure blood to the lungs to be purified; the left part distributes the pure blood throughout the body. Each part is again divided into two compartments. The two upper ones are called *auricles* and the two lower ones *ventricles*. Generally each cavity will contain about two ounces of blood. Between each auricle and ventricle is a valve which opens one way only. These allow the blood to flow from the auricle to the ventricle, but it cannot go back again (Fig. 119).

CIRCULATION OF THE BLOOD

The blood is pumped through the heart and circulates to every part of the body. It flows through a system of blood vessels, following a definite plan.

(1) The right auricle receives the venous or impure blood collected from the body by the capillaries. These tiny vessels join together, as do the tributaries of a river, and form two large veins: (*a*) the *superior vena cava* from the head, and (*b*) the *inferior vena cava* from the limbs and abdomen. These enter the right auricle. The blood then passes through a valve to the right ventricle.

(2) The right ventricle has thick muscular walls. By their movements the blood is pumped upwards through the *pulmonary artery* into the lungs. This artery divides into two, so that one passes to each lung. The arteries have thick muscular walls and in the lungs they divide

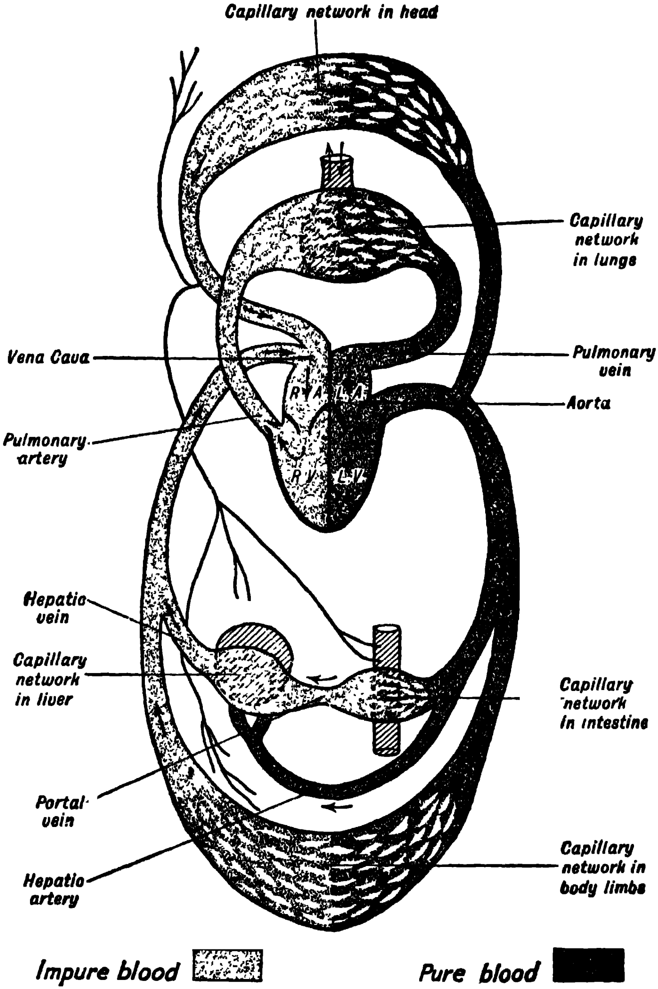


Fig. 120. Diagrammatic representation of the circulation of the blood

into smaller and smaller vessels, until the blood is in tiny capillaries. These lie around the air spaces in the lungs.

Here in the lungs the blood is purified, by giving up its carbon dioxide and impurities, and by being saturated with oxygen taken from the air drawn into the lungs. The pure blood, now brighter red in colour, is then collected into two pulmonary veins, one from each lung. These join up and return the blood to the heart.

(3) The left auricle receives the purified blood from the lungs. It then passes through the valve into the left ventricle.

(4) The left ventricle has a thicker muscular wall than any other part of the heart. By the contractions and expansions of these muscles the pure arterial blood is pumped into the *aorta*, the great main artery of the body. This divides into smaller arteries which divide again and again into still smaller ones, so that the blood is driven by the heart to every part of the body. In this way the blood containing oxygen and food is taken to all the tissues.

The capillaries become too small to be seen, and are so numerous that it is almost impossible to prick any part of our flesh without piercing them. These small vessels collect all the waste material of the cells as well as carbon dioxide so that it may be discharged from the body. They then join together, forming bigger and bigger tubes until they all unite into the big veins which take the blood containing the waste material back to the heart and lungs.

Thus the arteries convey the pure blood and the veins impure blood. The only exceptions are the pulmonary artery which carries impure blood to the lungs, and the

pulmonary veins which take pure blood back to the heart.

The diagram on p. 264 (Fig. 120) shows a plan of the circulation of the blood and gives the names of the chief veins and arteries. The aorta is the largest artery in the body. It is a tube about one inch across and formed chiefly of elastic tissue, so that it will stretch as the blood is pumped into it. Where this artery leaves the ventricle three valves prevent the blood from flowing back into the heart.

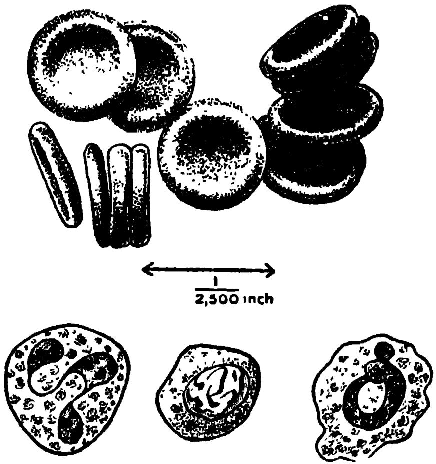
The aorta lies behind the breast-bone and bends towards the left of the spine, forming the arch of the aorta. Here it gives off three branch arteries which carry blood to the head, neck and upper limbs. The aorta itself runs down the back of the chest on the left of the spine and down to the abdomen, giving off branches to the chest, stomach, liver, spleen, kidneys and other organs. Finally the vessel itself divides, forming the two *femoral* arteries, one of which supplies the blood for each leg.

The pulse. The pulse is formed by the pumping of the heart. Each time the left ventricle contracts and relaxes, the blood is forced along the arteries in waves called the pulse. Normally, in a healthy person the pulse beats seventy-two times a minute. At night, when one is lying down, the beating is slower than when one is taking violent exercise or working. Ill-health also causes the beating to be irregular.

The pulse can be felt by placing the fingers on any part of the body where an artery is near the surface, though the usual place is over the *radial artery* in the wrist near the thumb.

STRUCTURE OF BLOOD

The human blood appears as a red liquid but really it consists of a clear fluid called *plasma*, in which are numerous red and white cells called *corpuscles* (Fig. 121). The *red corpuscles* are flat and round in shape and contain *haemoglobin* which gives the red colour to the blood. These cells take oxygen from the air breathed into the lungs and carry it to the tissues requiring it. They also collect carbon dioxide, which the tissues must get rid of, and send it out of the lungs. There are many more red corpuscles than white ones in the blood.



From Wells, Huxley and Wells' 'Science of Life", by permission of the Waverley Book Co.

Fig. 121. Human blood corpuscles. Red, above ; white, below

The *white corpuscles* are irregular in shape and in many ways resemble *Amoeba*. These cells help to destroy disease germs. When some bacteria enter the blood the white corpuscles kill and digest them as amoeba eats its food.

The plasma is a clear, yellowish fluid, some of which you have seen in a blister. The plasma transports the food to the parts requiring it. For this reason the *portal*

vein is very important, for it carries the blood containing food to the liver, where it is extracted and assimilated, or made into new products. In the liver the blood is also purified, for many things may be taken up which are unfit for nutrition, or perhaps absolutely poisonous. The liver therefore stands directly in the path of the circulation, and everything carried in the blood passes into it. It is often found that the liver retains these substances which would be poisonous to the system.

QUESTIONS ON CHAPTER 39

1. Give the names of the four cavities of the heart. How does the blood flow from one to the other?

2. What are (*a*) arteries, (*b*) veins, (*c*) capillaries?

3. Describe the circulation of the blood through the heart and lungs.

4. What differences are there in the blood flowing (*a*) into the lungs, (*b*) out of the lungs?

5. What is the pulse? How is it caused? Where can it be felt? What is the rate of the pulse in a healthy person?

6. What is the arch of the aorta?

7. Describe the red and white corpuscles of the human blood. What is plasma?

8. What do you know about the portal vein?

9. Where is the human heart placed? What is its size?

10. What are (1) the superior vena cava, (2) the inferior vena cava, (3) pulmonary artery?

11. Where does the blood flow after leaving the heart?

CHAPTER 40

THE HUMAN BEING (*continued*)

DIGESTION OF FOOD

DIGESTION is brought about by a series of chemical changes in the food, as it passes along the digestive tube or alimentary canal. Finally, food must be reduced to such a form that it can pass through the walls of this tube and enter the blood stream. In that way it is digested and absorbed. Then it is conveyed to all parts of the body where it is required. Water can enter the blood stream, but the various foods are broken down into simpler parts or digested by juice from glands on different parts of the digestive tube. Each juice has its own particular chemical reaction on the constituents of the food.

Fig. 122. The salivary glands

THE MOUTH

Digestion begins as soon as food is taken into the mouth. Here it is ground into fragments by the teeth and moistened with the *saliva*. This is a juice secreted by glands on both sides of the jaws (Fig. 122). It contains an enzyme called *ptyalin*, which has the power of changing

starch to sugar. Such a change is important, for you will remember that starch is insoluble, while sugar is soluble. Bread, potatoes and rice contain much starch, so that these foods pass through the first stage of digestion in the mouth.

Experiments

1. To show the alkaline reaction of saliva

Obtain a little saliva and test it with litmus paper.

Result. The saliva turns red litmus blue, which shows its alkaline nature.

2. To show the chemical reaction of saliva with starch

Apparatus. Starch solution, test-tube, iodine solution.

Obtain some saliva by taking warm water into the mouth, churning it, and then collecting it into a beaker. Make a starch solution in a test-tube and add some of the saliva. Gently warm the test-tube and after a few minutes add a few drops of iodine solution.

Result. No starch is present.

3. To test the solution for the presence of sugar

Boil the solution in the test-tube. Add Fehling's solution.

Result. The solution now forms a precipitate showing a sugar reaction. This shows that starch has been changed into sugar by the saliva.

The Gullet

In the mouth the food is rolled into little balls by the tongue and swallowed. It is then moved along the alimentary canal by means of the muscles in the walls.

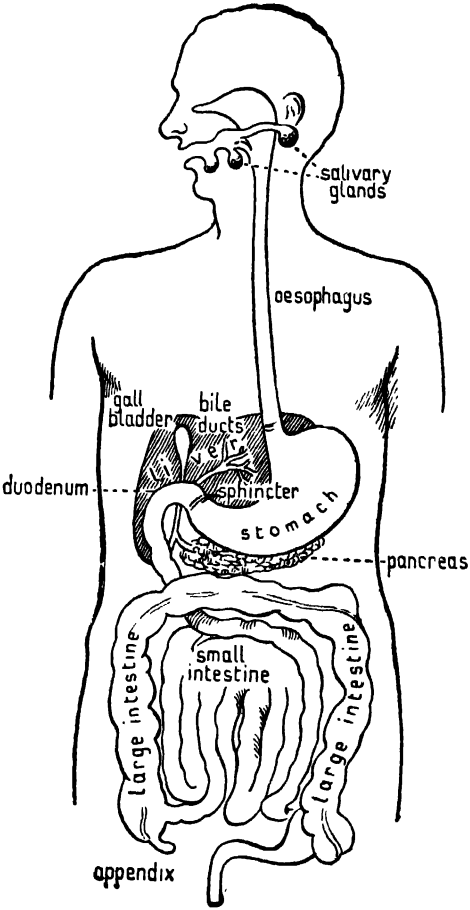


Fig. 123. The human digestive system

First it passes down the gullet or *oesophagus*, which is a long tube leading into the stomach (Fig. 123).

The Stomach

This is a strong muscular bag with a mucous lining. Here the food is pummelled and broken up by the muscles and is mixed with a fluid called *gastric juice* which is secreted by glands in the wall of the stomach. This contains hydrochloric acid and a ferment called *pepsin* which gives a reaction opposite to that of saliva. It therefore stops the digestion of starch, and it breaks down proteins into simple compounds called *peptones*. It also produces some reaction with sugar foods. Generally the food remains in the stomach for about three hours, though some foods take longer to digest than others. Before leaving, the food is thoroughly churned up into a semi-fluid substance and is known as *chyme*.

The Duodenum

This is a tube about a foot in length leading out of the lower end of the stomach; it is the first part of the small intestine. The food passes out of the lower end of the stomach into the duodenum. Here it is joined by two ducts which bring juices from two large glands or secreting organs, the *liver* and the *pancreas*. The juices from these are alkaline.

The Liver

The liver stores a special kind of starch and secretes a greenish fluid called *bile*, contained in a little bag called the *gall bladder*. This has the property of emulsifying or breaking up the fats of the food into minute globules.

The Pancreas

This is sometimes known as the sweetbread. The juice from this gland has the same emulsifying effect upon fats, but it also contains sodium bicarbonate, and so has an alkaline reaction as well. Therefore it stops the acid reaction of the gastric juice, and is also able to break up the remains of proteins and sugars. With this the digestion is nearly complete.

The digested food makes its way through the thin membranes lining the small intestine and passes into the blood. In the blood stream it is first taken by the portal vein to the liver, where it undergoes further chemical changes and is then distributed round the body by the circulation of the blood.

The Intestines

After leaving the duodenum, a portion of the food remains undigested. These substances pass along the small intestine, which is a tube, measuring about twenty-five feet long, joining the duodenum and large intestine. There digestion is finally completed. Any undigested food then goes into the large intestine, to the beginning of which the *appendix* is attached. This is a small tube about four inches long, but as it is closed at one end it does not really form part of the food canal.

Finally the undigested food, a little water and other waste products reach the last stage of their journey. They pass into the *rectum*, from which they are discharged through the *anus* and so leave the body.

QUESTIONS ON CHAPTER 40

1. What do you understand by digesting food?

2. What changes are made in the food while it is in the mouth?

3. Describe an experiment to show the chemical reaction of saliva on starch.

4. Where is the gullet?

5. Describe the stomach. What changes in the food are made in the stomach?

6. What do you know about (*a*) ptyalin, (*b*) pepsin?

7. Where is the duodenum?

8. Write what you know about the liver. What is bile?

9. What is the pancreas? What effect has the juice from this gland on the undigested food?

10. What is the (*a*) small intestine, (*b*) large intestine, (*c*) appendix?

11. What happens to the (*a*) digested food, (*b*) undigested food?

12. In which part of the food canal are (*a*) fats, (*b*) proteins, (*c*) starch foods changed in the process of digestion?

CHAPTER 41

THE HUMAN BEING (*continued*)

KINDS OF FOODS

MAN'S diet consists of a mixture of plant and animal food, since it includes fruit and vegetables, which are parts of various plants, and meat, which is the flesh of various animals (Fig. 124). All the animals which provide meat for man feed on vegetable produce; therefore we depend entirely on plants for our food. In this way all the energy of man and animals is derived directly or indirectly from the sunlight.

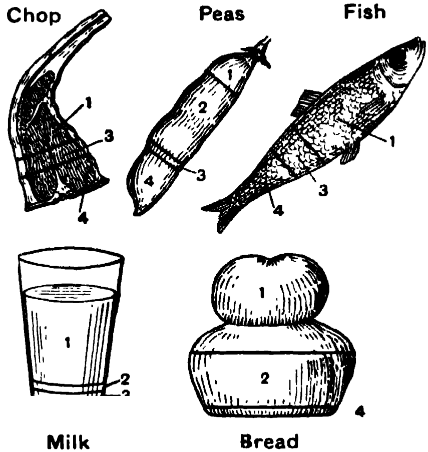


Fig. 124. Proportion of foods in articles of diet. 1, water; 2, carbohydrates; 3, fats; 4, protein

Foods possess varying amounts of this energy absorbed from the sun, and this is known as energy value. After food is digested this energy, which it stored, is liberated, just as stored sunlight is liberated during the burning of coal.

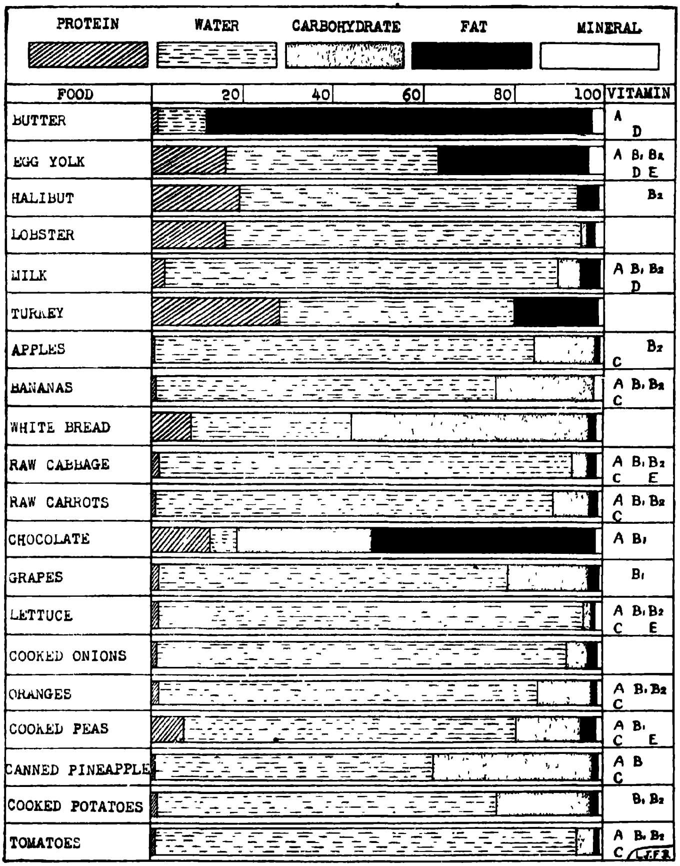


Fig. 125. Percentage composition of foods and vitamins in certain articles of diet

All living creatures are composed of cells consisting of protoplasm. When analysed chemically this living

substance is found to consist of carbon, hydrogen, oxygen and nitrogen, so that all living organisms require these elements to build up their bodies.

The human body is built up of many kinds of tissue. For this reason a mixed diet is necessary for man. Consequently, scientists have carefully analysed the various kinds of foods, and have arranged them in four groups, carbohydrates, proteins, fats and salts.

(1) **Proteins.** These are required to build up new cells to replace the old ones which break down or wear away. Eggs, cheese, milk, meat and fish contain these foods.

(2) **Carbohydrates.** These supply the body with energy necessary to perform its activities. Sugar and foods made chiefly of starch, as bread, potatoes and rice, contain carbohydrates.

(3) **Fats.** These give heat and energy required by the body. Fat foods are contained in cream, butter, fat meat, etc.

(4) **Mineral salts.** In addition to these foods our bodies require mineral salts and water to keep them nourished and healthy.

Vitamins. There are still needed other substances classed as vitamins. These are very important and are found in fresh milk, fresh fruits, vegetables, cod liver oil and other foods (Fig. 125).

Food Analysis

Milk. Cow's milk contains all the necessary foods and so it is known as a complete food. It consists of:

Water - - - -	87 per cent.
Solid matter - - -	13 per cent.

The solid matter is composed of:

Fat (cream) - - -	3·5 per cent.
Carbohydrates (milk sugar)	5·0 per cent.
Proteins - - - -	3·5 per cent.
Ash (minerals) - -	1·0 per cent.

Experiments

1. To find the kinds of food in milk

Pour 50 c.c. of milk in a graduated jar. Allow it to stand for about an hour.

Result. The cream, which is fat, rises to the top. Measure the amount separated from the milk. This shows what percentage of the milk is cream.

2. To test for fat in milk

Drop a little cream on a piece of white paper. After a few minutes wipe it off and hold the paper up to the light.

Result. The paper shows a grease mark of fat.

3. To find the percentage of water in milk.

Apparatus. Evaporating dish, graduated jar.

Weigh an evaporating dish. Measure 20 c.c. of milk and run it into the dish. Weigh the dish containing the milk. Place the dish on a sand tray and evaporate the milk over a Bunsen flame. When the liquid has apparently evaporated, place the dish in an air oven at 100° C. for about twenty minutes. Allow the residue to cool and weigh the dish again.

Result. The difference in weights = weight of water.

$$\text{Percentage of water in milk} = \frac{\text{Loss in weight}}{\text{Weight of milk}} \times 100.$$

4. To show that milk contains proteins

Mix one part of the residue with two parts of lime. Place it in a test-tube and heat over Bunsen flame. Hold damp pieces of red and blue litmus paper in the mouth of the tube and smell the fumes.

Result. Ammonia gas is given off and turns red litmus blue. Ammonia is a compound of nitrogen and hydrogen, so this gas proves the presence of a nitrogenous substance which, in this case, is a protein.

5. To show that milk contains carbohydrates

Place another portion of the residue from the evaporated milk in a crucible and heat over a Bunsen flame.

Result

(*a*) The residue is charred and only a white ash remains in the crucible. The charring shows that the residue contained carbon, hydrogen and oxygen. A carbohydrate is a compound of these elements.

(*b*) The white ash which remains after heating consists of mineral salts.

PROTEINS

Proteins are substances which are found in all types of living matter and in such foods as white of egg, curd of milk, lean meat, beans, peas, cheese and fish. Proteins are composed of the elements carbon, hydrogen, oxygen and nitrogen. They are the only foods containing nitrogen in a form required for nutrition. They are known as nitrogenous foods and, as a rule, form the chief items of each meal.

Proteins are needed for building up protoplasm for the growth of the fleshy tissues for the repair of muscles; and, because of this, they are sometimes called flesh-formers. They also help in the formation of digestive juices and, like all other foods, they also give heat to the body.

Proteins are complex substances, but in the process of digestion they are broken down by ferments, known as pepsin in the stomach and trypsin in the intestine.

Carbohydrates

Carbohydrates are food substances which contain carbon, hydrogen and oxygen, and, strange to say, the hydrogen and oxygen are in the same proportion as in water. Carbohydrates include sugar and starchy foods, and are the simplest of all foods. Plants make their raw materials into sugar and starch and change them from one to the other, as they require to use them or store them as food.

Bread, potatoes and rice are our chief foods containing carbohydrates; but when we eat these foods, the starch in them must be changed to sugar, before it can be used in nutrition. This is done by the saliva, and then the sugar is soluble in water and can be directly used by the body. Sugar readily burns and so gives heat and energy to the body. Carbohydrates, therefore, are energy-giving foods.

Fats and Oils

Fats and oils are also compounds built up of carbon, hydrogen and oxygen. When carbon and hydrogen are burnt in oxygen they give out enormous amounts of heat.

Fats are contained in such foods as cream, butter, margarine, suet, lard, milk, dripping and all fat meat. All these are heat-giving foods.

Mineral Salts

Salts are essential to health and life too. Ordinary common salt (sodium chloride), the chief of them, is found in every part of the body, in the blood and in certain digestive juices. Salts of iron are required to give colour and strength to the blood. They are necessary for the formation of haemoglobin, which carries oxygen from the lungs to the tissues throughout the body; and potassium salts are required to keep the blood pure. Phosphorus tones up the nerves, and this and calcium salts help to form teeth, bones, nails and hair.

All these salts are contained in an ordinary mixed diet and especially in beans and peas.

Water

Water is most essential; in fact its importance cannot be over-estimated. It is a solvent and aids in reducing solid foods to a liquid state necessary for entering the blood. Water is found in every part of the body, which requires about two quarts per day. It forms a large percentage of the blood and of the digestive juices. It distributes food, discharges waste products, and, by means of perspiration, water helps to equalise the temperature of the body.

Some foods contain all four food groups—proteins, carbohydrates, fats and salts. They are complete, and contain all that is necessary to support life.

Milk and eggs are examples of complete foods. Eggs are a most valuable form of food. Peas, beans and many other seeds contain all the food necessary to form a fully developed seedling. Seeds, therefore, possess a store of valuable food.

A few simple tests will prove the presence of these foods in a hen's egg.

Analysis of a hen's egg. A hen's egg consists of a shell of calcium carbonate which contains a yellow yolk surrounded by a transparent whitish fluid.

Experiments

1. To test for proteins in an egg

Apparatus. Two beakers, egg, copper sulphate solution, caustic soda solution.

Break an egg and place the white in one beaker and the yolk in the other. To the white add one drop of copper sulphate solution and then two or three drops of caustic soda solution. Watch the colour change.

Result. The substance changes to violet in colour. This colour indicates the presence of protein.

2. To find the proportion of water in an egg

Apparatus. An egg, crucible, sand tray.

Weigh a crucible. Break an egg and beat together the white and yolk in the crucible. Weigh again. Stand the crucible and contents on a sand tray and heat them over a Bunsen flame to drive off the water as steam. Weigh again.

Result. The difference between the two weights is due to the loss of water. This represents the amount of water contained in the egg, which is about 70 per cent. of the contents of the egg.

3. (*a*) To show the presence of ammonia in an egg

Heat the dry substance from the above experiment and hold pieces of damp red and blue litmus paper in the fumes. Notice the smell of the gas.

Result. The fumes turn the red litmus blue and the smell shows the presence of ammonia, which is a compound of nitrogen.

(*b*) **To show the presence of carbon**

The substance, which is fat, slowly burns, giving off carbon dioxide gas.

(*c*) **The white ash which remains consists of mineral salts**

Analysis of cheese. Cheese is also a complete food.

4. To test for protein, etc., in cheese

Apparatus. Piece of cheese, crucible, copper sulphate, caustic soda solution.

(1) Place a piece of cheese in half a test-tube of water and warm gently over the Bunsen flame. Add one drop of copper sulphate solution and two or three drops of caustic soda solution.

Result. The colour changes to violet.

(2) Place a piece of cheese in a crucible and heat over the flame. Hold pieces of red and blue litmus paper in the fumes and smell the gas.

Result.

(*a*) The fumes turn red litmus blue.

(*b*) The gas indicates ammonia, which, as you remember, is a compound of nitrogen.

(*c*) The fat burns, which shows the presence of carbon.

(*d*) The white ash which remains consists of mineral salts.

Further tests for foods. Following the methods described in this chapter, test various articles of diet, such as apple, onion, raisin, potato, lean meat, etc., for carbohydrates, proteins and fats.

Tests for mineral salts

Mineral salts are present in nearly all common articles of diet.

Experiments

1. To find the mineral salts in peas or beans

Apparatus. Peas or beans, crucible, quick lime, litmus paper.

(1) Crush a few peas and mix them with quick lime. Heat the mixture in a test-tube over a Bunsen flame.

Result. Fumes of ammonia gas are given off, showing that peas contain proteins.

(2) Place some of the pea flour in a crucible and heat in a hot flame. Observe that part burns very brightly, indicating the presence of carbon. Continue to heat the substance, until only white ash is left. It can be shown that the white ash consists of salts formed from the alkaline metals calcium, sodium and potassium. To the white ash in the crucible add a few drops of dilute hydrochloric acid. Hold a little on the end of a piece of platinum wire in a Bunsen flame. Observe the colour of the flames.

Result.

If the flame is yellow it indicates sodium.

If the flame is black, or red through blue glass, it indicates potassium.

If the flame is red, or green through blue glass, it indicates calcium.

VITAMINS

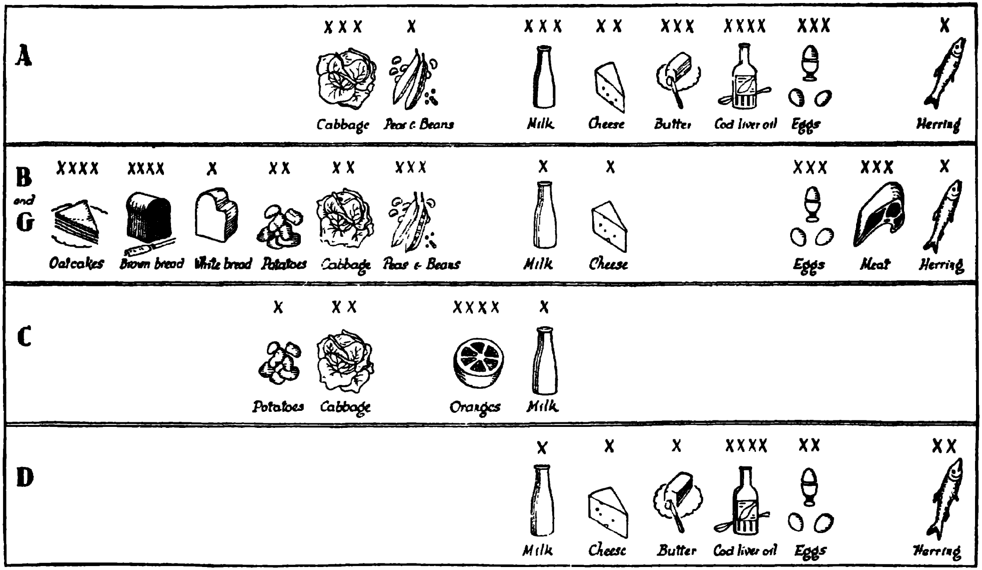
During recent years scientists have given much time to the analysis of the various kinds of food forming man's diet. They have decided the food value of many things we eat and their use in building up the body and supplying it with energy. They have discovered that the real nutritive value of foods depends largely upon the presence of certain substances known as *vitamins*.

Vitamins are present in food stuffs in very small proportions, but they are of great importance. A diet without them leads to an unhealthy condition of body and causes various kinds of diseases, while an adequate supply of them gives the body power to resist certain diseases.

There are various kinds of vitamins. Some tone up the nerves; some build up bone and teeth; some are necessary for growth in children; while others are essential for good health. Consequently, vitamins have been classified according to their effect and value in food.

Vitamin A is present in milk, butter, cheese, yolk of egg, beef and mutton fat, liver, carrots and fresh green vegetable food. This substance greatly aids growth in children, and helps the body to resist certain diseases.

Vitamin B is present in the embryo and husks of



By courtesy of the B.B.C.

Fig. 126. Vitamins in common foods. The crosses indicate richness in vitamins

cereals, yeast, milk, egg yolk, liver, cabbage and lettuce. This vitamin is also necessary for growth and for a healthy nervous system.

Vitamin C is present in fresh vegetables and fruit, especially lettuce, cabbage, turnips, watercress, potatoes, oranges, lemons and tomatoes, but is absent from cereal foods. Vitamin C is destroyed by prolonged cooking or by exposure to air. This substance is important and prevents scurvy, which formerly was a disease common among sailors who were obliged to live on preserved food while at sea.

Vitamin D is found in cod-liver oil, fat meat, fish, egg yolk and butter. This substance helps to harden bone and prevent decay of teeth. To some extent its absence may be replaced by sunlight (Fig. 126).

To keep the body healthy it is necessary to have a mixed diet, so as to include some of all the classes of food and vitamins.

QUESTIONS ON CHAPTER 41

1. Why does man need a mixed diet?

2. Give the groups into which our food may be arranged.

3. What are proteins? Give the names of three foods containing proteins.

4. What are carbohydrates? Give examples of three kinds of food containing carbohydrates?

5. Explain why milk is said to be a complete food.

6. Describe four experiments to show that milk is a complete food.

7. What are salts? Why are they considered to be essential to good health?

8. Describe an experiment to show that an egg contains proteins.

9. Describe the contents of a hen's egg. Is it a complete food?

10. How could you show that grape sugar is present in an apple?

11. How could you show that a carbohydrate consists of carbon, hydrogen and oxygen?

12. How could you show that peas contain mineral salts?

13. What are vitamins. How are they classified?

CHAPTER 42

THE HUMAN BEING (*continued*)

THE NERVOUS SYSTEM

MAN acquires his knowledge and uses his intellect by means of his *brain*, *nerves* and *sense organs*. These form the nervous system. In the human body it is more developed than in any other animal. The brain is enclosed in a bony case, the skull. From the brain grows the spinal cord which passes down through the backbone, and from it numerous nerves branch to all parts of the body (Fig. 127).

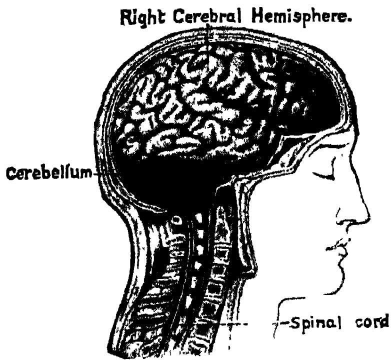


Fig. 127. The brain and spinal cord

The brain. This is a large mass of spongy substance, greyish in colour, and shows three distinct regions. The surface is uneven, presenting irregular ridges and furrows, and is protected by a small quantity of fluid and membranes. The brain is the seat of intelligence, memory and understanding. It makes us conscious of what goes on around us. It stores our knowledge, enables us to reason and controls our actions.

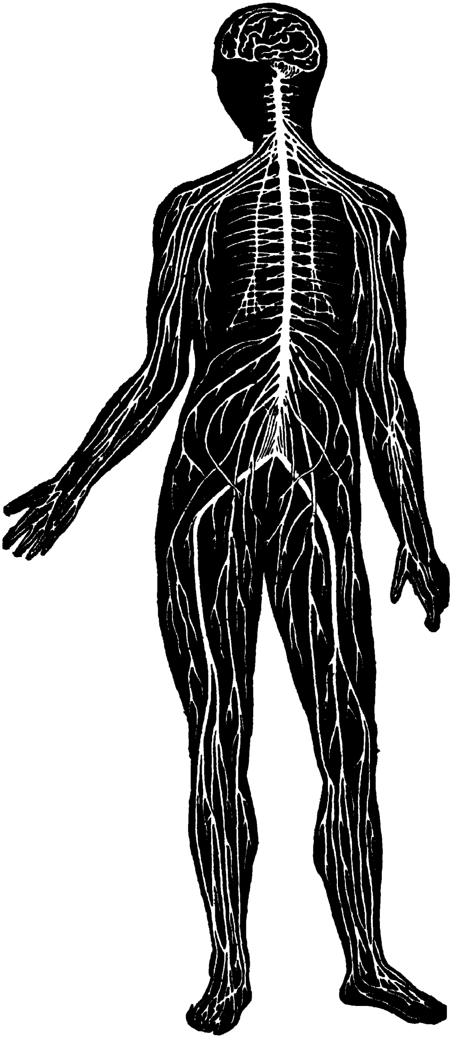


Fig. 128. The human nervous system

The spinal cord. This is similar in substance and about the thickness of a small finger. It passes from the under surface of the brain through a hole at the base of the skull and down the spinal canal formed by the vertebrae of the backbone.

The nerves. The nerves look like thin white threads. Some start from the base of the brain and run to the special sense organs. The optic nerve, for example, passes to the eyes and is concerned with vision ; others go to the nose, ears, tongue and skin and cause sensations of smell, hearing, taste and touch.

Other nerves grow out from the spinal cord. These pass to the limbs, muscles, internal organs and skin, and branches from them go all over the body (Fig. 128).

How the Mind acquires Knowledge

The nervous system forms a kind of telephone system. The brain is the centre, or exchange, and the spinal cord is the great trunk line. The nerves are the telephone wires along which messages, or impulses, travel from the sense organs, skin, etc. and back from the brain to other parts of the body.

Certain parts of the brain are concerned with definite parts of the body. One part controls the limbs ; another sensations of touch and temperature ; and other parts are concerned with vision, speech, hearing, thinking, etc. These various parts are connected by the nerves with the distant parts with which they are concerned.

Those which control the left side of the body are on the right side of the brain, and those on the right side of the body are connected with the left side of the brain.

There are apparently two kinds of nerves. (*a*) Those which convey the messages or impulses *to* the brain are called *sensory nerves*. (*b*) Those which take messages *from* the brain and spinal cord are known as *motor nerves*. Messages sent along the sensory nerves arouse in the brain sensations of feeling, tasting, hearing, smelling, seeing, temperature and pain, and the brain knows the part from which the message is sent. The motor nerves take messages from the brain and cause muscles to contract.

If a fly bites your right hand you instantly shake it off. This quick action is caused by the nerves. As soon as the fly settled on your hand a message was sent along a sensory nerve to the spinal cord. Immediately an impulse was sent down the spinal cord to the motor nerves of the muscles of the arm, thus causing the hand to shake off the fly. A message was also sent from the spinal cord to the brain and you were aware that you had been bitten and that you had shaken off the fly.

All the cells composing the human body work together for its general health and protection. Indeed, the cells forming every living creature cooperate for its well-being. Thus, as in the case of the fly, if one part is attacked, all others join in its defence. Instantly a warning message is flashed to the spinal cord or brain which sends immediate orders to the muscles to defend the part attacked.

QUESTIONS ON CHAPTER 42

1. What forms the nervous system in the human body?
2. Describe the human brain and spinal cord.
3. What is the optic nerve?

4. How does the mind get knowledge?

5. What are the two kinds of nerves?

6. Describe how the nerves operate when a fly bites the hand.

7. What do you understand by the statement that in the human body all cells work together for its health and protection?

CHAPTER 43

THE ORIGIN OF LIFE

It is now definitely known that every living creature—plant, animal and man—begins life as a single cell. In most cases this is formed by the union of two particles of the germ cells ; one supplied by each of its two parents. In this way life has been passed on from generation to generation for millions of years ; but how and when life started on the earth is still unknown. Many theories have been propounded by different scientists, but as yet they do not agree how and when the earth itself was formed. Some believe that the earth may be some two thousand or three thousand million years old, and that when it was first made it was a hot molten mass on which life was totally impossible. Then as time went on it gradually cooled and hardened, and so the various layers of rocks were formed.

Eventually, but still in those early geological times, life appeared on the earth. When and how it came remains a mystery. Living matter, some say, was formed from matter that had no life.

Evolution

Plants and animals are found as fossils in these ancient rocks. Scientists say that when these were alive they were entirely different from those that live to-day.

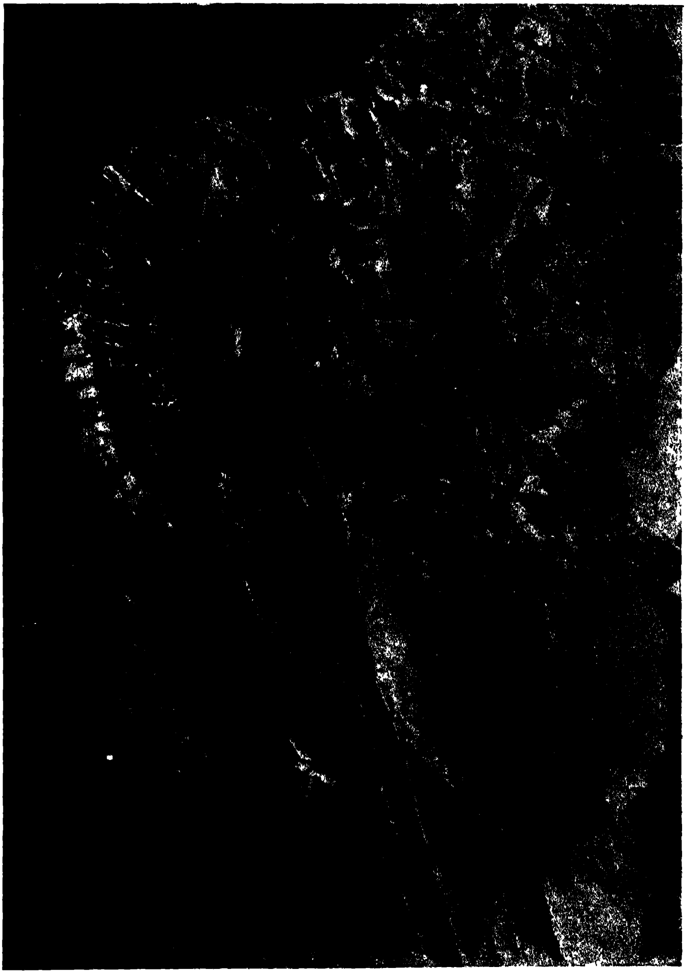
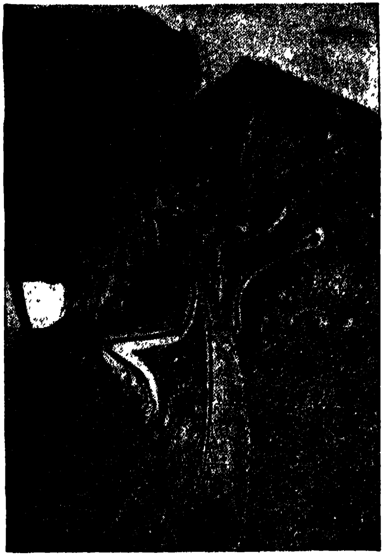


Fig. 129. Fossil plants on rock

(Scott, "Extinct Plants and Problems of Evolution": from a photograph supplied by Dr. Wieland)

Neither man nor even angiosperms were yet in existence, for their fossils are not found in the oldest rocks. From day to day, however, Nature slowly changes, and gradually, through the millions of years, life on the earth has changed and thus the creatures alive to-day have *evolved.*



The British Museum (Natural History)
Fig. 130. A fossil bird

From the fossils found in some ancient rocks we have evidence that living matter existed in these pre-historic times (Figs. 129 and 130). Protoplasm is its name, and could they but find out how it can be made, then scientists might know the greatest of all mysteries—the origin of life.

Protoplasm is a most complex substance. Some believe that it was first formed in the sea and that then life was so simple that there was no distinction between plants and animals. Then gradually, through the long ages of time, plants and animals slowly developed along their respective lines, producing as they do to-day varying types of every degree of development and complexity.

This belief, that plants and animals living to-day have evolved from remote and elementary forms, is known

FIG. 131. Charles Darwin

as the *theory of evolution*. It was first clearly formulated by *Charles Darwin*, a great scientist born in Shrewsbury in 1809 (Fig. 131). He published the theory in his famous book called the *Origin of Species by means of Natural Selection* in London in 1859, and since then many biologists have accepted this explanation. In his book, Darwin not only explained the evolution of plants and

animals from the lowest to the highest forms, but also pointed out that these groups of plants and animals which closely resemble each other have descended from a common ancestor.

All plants or animals of the same kind are classed by scientists in a single group called a species, because Darwin believed that they all sprang from the same ancestor.

Variation in Species

All plants and all animals vary slightly, though they belong to the same species. No two are exactly alike nor are any two people exactly alike. Even children of the same family, who bear the same family likeness, are different from one another.

Such variation found in species has led scientists to find out that every plant and every animal also differs from every other member of its family. This variation, Darwin explained, is the result of the struggle for existence in which the weakest members of the race die out and the strongest and most adaptable live. Throughout the ages plants and animals have developed in a natural way. They have become more complex in structure to adapt themselves to their environment. In this way man has become the most advanced of all creatures, not only in body but also in mind.

Heredity

Darwin pointed out that each generation inherited, in some degree, the characteristics of parents. Such features as colour of hair and eyes, size and form of each of the parents, are handed down to their children.

Fig. 132. Gregor Mendel

The transmission of characters from parents to offspring is known as *heredity*.

The first experiments towards the discovery of the way in which characteristics are inherited were made by *Gregor Mendel*, an Austrian abbot who lived from 1822

until 1884 (Fig. 132). He made his experiments with tall and short peas in the garden of his monastery at Brunn (Brno). At first little importance was attached to his work and, though his results were published in 1867, it was not until 1900, some years after his death, that scientists realized that Mendel had made most important discoveries about the great laws of Nature. He had shown that qualities and characters of parents were transmitted to their children by the living substance of the germ cells and that these qualities and characters are passed on from parent to child according to a definite plan in Nature. He showed also why a character which was not apparent in either parent might appear in the offspring, and explained that it is inherited from the grandparent.

Plant and Animal Breeding

After Mendel's work became known, numerous similar experiments were carried out by other scientists and the rule became known as Mendel's law. Soon it was realized that this knowledge would be valuable to breeders of animals and plants. It enables them to produce those possessing only desirable qualities, and many new types of flowers, fruit and vegetables are now obtained by using this knowledge. Similar results have been obtained by breeders of animals. It is important for them to know the qualities of grandparents, because from them weak characteristics may be handed on, and these may appear in future generations. This fact should also be known by all people, since it has been discovered that weak-mindedness and certain diseases may appear in the child

of normal parents, because they have been handed down from the grandparents. It is, therefore, important when choosing a life partner to consider what possible qualities or defects may be handed on to future generations.

QUESTIONS ON CHAPTER 43

1. How do scientists account for the varying types of plants and animals living to-day?
2. What was the title and date of Charles Darwin's famous book?
3. What was the theory explained by Darwin?
4. How does Darwin account for the variation in plants and animals?
5. What do you understand by Heredity?
6. What do you know about Gregor Mendel?
7. How did Mendel discover a great law of Nature?
8. What use is the knowledge of Mendel's law to stock breeders and florists?
9. Why is this knowledge important to human society?

CHAPTER 44

HEALTH AND FITNESS

Cleanliness

Personal cleanliness is very important to health and fitness.

The skin. The skin of the whole body should be washed with soap and water frequently. Waste products are discharged through the skin and this makes washing essential. The skin is the natural covering and consists of an upper layer, or *epidermis*, and a lower, or *dermis*, which is the true skin.

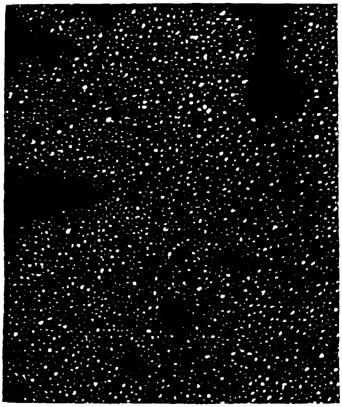


Fig. 133. Surface of the skin specially treated and magnified to show minute openings of the sweat glands

The epidermis is made up of flat horny scales, which are constantly being cast off and replaced by new ones from underneath. This upper layer forms a protection for the dermis below, and it is perforated by innumerable minute pores. These are openings of tiny tubes or ducts which pass down to the bottom of the dermis where they coil into little balls and

are surrounded by numerous blood vessels. These ducts are really *sweat glands* and it is their work to remove, in the form of sweat, useless substances from the blood (Figs. 133 and 134). These substances, which are poisonous if left in the body, pass along ducts through the pores and are poured out on the surface of the skin as perspiration.

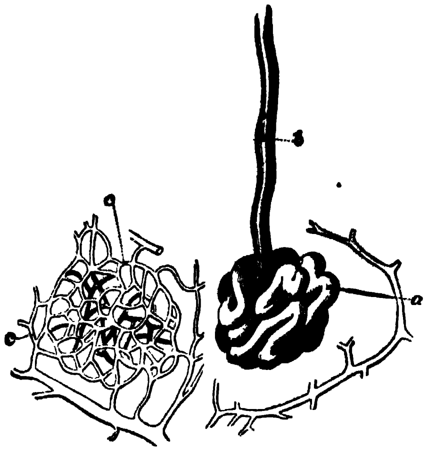


Fig. 134. Sweat gland (*a*) with its duct (*b*), on the right; the capillary network (*c*) in which it lies, on the left

The dermis also contains oil or fat glands. They too remove waste matter from the blood and also lubricate the hair, and prevent the skin from cracking.

Perspiration, or sweat, is really a watery fluid containing various dissolved mineral salts, especially common salt. When we are cold the glands stop sending out their perspiration; when we are hot they pour out great quantities.

By washing the skin the dead scales of skin and the excretions from the pores are removed. If they are allowed to remain on the surface they decompose and give off an offensive smell. The pores remain blocked, so that more perspiration cannot get out. Then the poisonous matter is retained in the blood and causes ill-health.

"Where there's dirt there's danger"

Dirt also helps in spreading infectious diseases for, generally, epidemics spread most rapidly in dirty districts. In fact, typhus fever is carried by lice that can live only on people who do not wash properly, and some skin

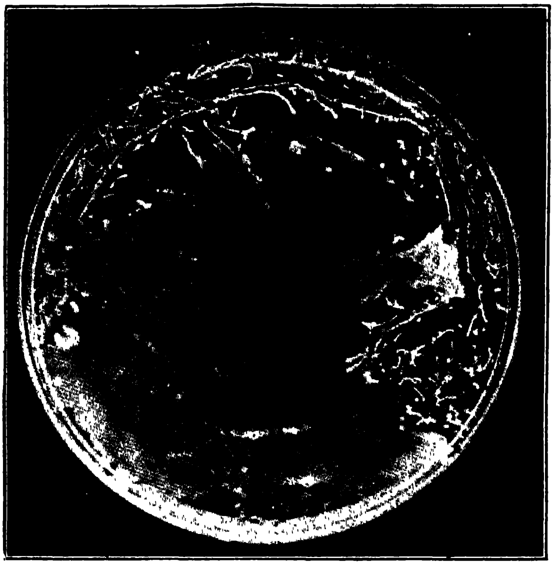


Fig. 135. Bacteria growing on an agar plate after a housefly had been allowed to crawl over it for three minutes

diseases are mainly produced by dirt. Fleas and lice live among filth and give germs to dirty people. The terrible disease called bubonic plague is carried by the fleas which live on rats. If a flea bites a diseased rat the germs will live and multiply in its mouth. If it then bites a man it will give him the disease. The Great Plague of

London in 1665 was the bubonic plague and came in this way. The common house-fly and gnat are dangerous for a similar reason.

Flies like to crawl over filth and then they bring the germs on to our food and milk (Fig. 135). Spores of bacteria float about in the air and settle down in dirt and dust. When they are disturbed they reproduce themselves and give diseases to people.

The skin also serves as a sense organ and is a means by which we become aware of contact with other objects. If it is covered with dirt it is, of course, less sensitive. In such a condition it does not allow the temperature of the body to be properly regulated, so there is a tendency to catch cold.

Dirt also encourages terrible skin diseases ; one of the worst is due to a horrible little parasite called the itch mite. This dreadful creature burrows below the epidermis, where it lays its eggs and thus increases its numbers very quickly.

The hair. The hair needs very special attention, because it is always exposed to dust and germs. It should be thoroughly brushed each night and morning in order to remove the loose flakes of skin from the scalp and to stimulate the circulation of the blood which keeps the hair well nourished. By nature hair is greasy to prevent it from breaking ; but to remove excessive grease and dust it should be washed at least once a month in warm water to which has been added a little ammonia.

The nails. Finger nails also require special attention for they are a real source of danger, if they are not kept scrupulously clean. They are formed of hardened layers of epidermis and protect the tips of the fingers and toes.

Finger nails are very liable to collect dirt; and infectious diseases have been known to be spread by allowing dirt to remain under them.

The teeth. The teeth also need very special care. They should be brushed every night and morning to remove particles of food which lodge between them. If neglected, germs soon attack the teeth and cause them to decay. Then follow bad digestion and ill health.

Clothing. Clothing, too, is an important factor in the maintenance of good health. All clothing should be clean and all under garments should be washed regularly. The main purpose of wearing clothes is to keep the body at an even temperature. The normal temperature of the blood is 98·4° Fahr., and suitable clothing should prevent heat from the body passing into a cooler atmosphere. The garment next to the skin should be made of wool, or of other material capable of absorbing perspiration, which would otherwise evaporate quickly and chill the body.

Fresh Air

Fortunately it is now realized that fresh air is essential to good health. It is important that the air we breathe should be well supplied with oxygen, for this is necessary for the maintenance of life. Therefore all buildings should be well ventilated.

Abundant fresh air and proper breathing are important to nutrition. Many children do not breathe properly through the nostrils. They should practise breathing exercises and nose drill every morning, to inflate the lungs properly and to remove from them the stagnant air.

Free circulation is also necessary to carry away mois-

ture and heat given out by the human body through the skin. In a crowded room the air soon becomes charged with moisture and reaches a high temperature. In these circumstances inadequate ventilation causes drowsiness,

By courtesy of the L.C.C.

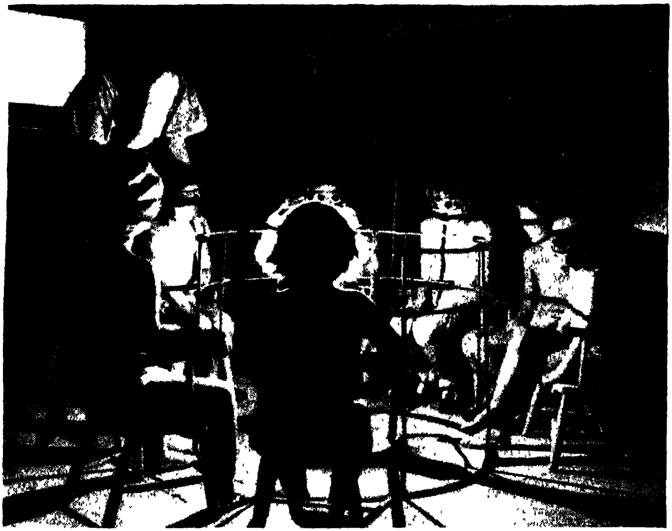
Fig. 136. An open-air class in gardening

headache and discomfort, because the body is unable to give out heat and moisture to the air which is already humid and too warm. Such conditions become a great strain on the working of the body and give rise to ill health (Fig. 136).

SUNSHINE

Our bodies work best when the air is cool and dry, for then we can make more heat by food and exercise to

replace what is being used. Sunlight is essential to the healthy development of both animal and vegetable life. Sunshine also kills most kinds of disease germs, so a bright, airy room is healthier than one darkened with curtains and where the doors and windows are always shut.



Valdar Publicity Service

Fig. 137. Artificial sun-ray treatment in a London clinic

During the winter sunshine is scanty, but the lack of it can be made up to some extent by taking cod-liver oil which contains the substance that sunshine produces by its action on the skin. That substance is Vitamin D which is manufactured by ultra-violet rays from the sun. Similar treatment is supplied by ultra-violet lamps ("artificial sunlight") supplied in clinics and hospitals (Fig. 137).

Diet

Food builds up new living material ; and, when we are young, much is needed for this purpose ; while throughout life, worn tissues must be repaired. Food, after it has been digested and stored, also serves as a fuel. It joins with oxygen and the slow combustion gives heat and energy to the body to keep the parts working.

In accordance with these two functions foodstuffs are divisible into two great classes. The first includes the *protective foods*, so called because they are rich in substances—proteins, mineral salts, and vitamins—which build up the body and protect it against disease. The principal foodstuffs of this class include milk, green leaf vegetables, whole meal bread and fruit.

The second class consists of *energy-yielding foods* or fuel foods, so called because they are rich in substances—starch, fats and sugar—which provide energy for the work of the body. Included in this class are the cereal foods—flour, bread, rice, barley, oatmeal ; the fats, such as mutton fat, beef fat, bacon fat, butter, margarine and vegetable oils ; and sugar, either as such, or in honey, treacle and sweet things generally. Meat, too, is an energy-yielding foodstuff.

The human diet must be varied and balanced to include protective and energy-yielding foods, because the bones and various tissues forming the body require their own particular kind of nourishment. When these foods are properly combined they form a complete diet, and should be varied to satisfy the natural appetite. This will depend upon the mental and physical activity and amount of energy spent by the individual. People who use much

energy require nourishing and energy-giving food. Individuals should eat what pleases their own natural appetite and should make the meal a real pleasure.

Exercise

Proper exercise of the body forms an important factor in the health of the individual and consequently in that of

By courtesy of the L C C.

Fig. 138. Girls doing physical exercise in the open air

the state. Not only does it promote muscular strength, agility and beauty of form, but it stimulates the circulation and purification of the blood.

Exercise helps to use up food materials quickly ; to maintain a healthy circulation of the blood for the distribution of nutrition and oxygen ; and to discharge waste substances more thoroughly.

Frequent and regular exercises and an active life prevent ill-health. Many physical exercises are also good mentally and morally in that they enable us to con-

By courtesy of the L.C C.

Fig. 139. Boys doing physical exercise in the gymnasium

trol our muscles and reactions, and conduce to quickness and concentration of mind. Physical exercises should be taken in the open air, in sunlight if possible, and in very light loose clothing, but not immediately after a heavy meal (Figs. 138 and 139).

Rest and Sleep

Our ability to work, either physically or mentally, depends upon the amount of energy available. This is supplied by food; but, if the amount used exceeds the supply, the body becomes exhausted. When this happens

waste products, known as toxins, are formed. These soon accumulate and produce symptoms of fatigue. This is a warning that the output of energy must stop and that the tissues and organs must rest.

During rest or sleep the toxins are carried away, the store of energy in the cells is replenished and the bodily strength is renewed. If the warning is ignored, more symptoms follow. Soon concentration becomes difficult; memory fails; then prolonged neglect of rest leads to lack of control and finally to a nervous breakdown.

Sleep is Nature's nurse for animals as well as for man. Just as Nature demands regular meals and suitable food, so she demands regular hours of sleep. To regain energy spent during the day a growing child of school age requires ten or twelve hours' sleep, and an adult should be allowed seven hours at least.

Sleep should be undisturbed and nothing should prevent anyone from taking it at regular times. The room where sleep is taken should be quiet and have a window open to keep the air in motion. During sleep respiration becomes slower and deeper, and, in harmony with this process, the heart beats more slowly too.

When entering the room to sleep all cares and worries should be shut outside, so that the brain may rest too, for a troubled mind always prevents a deep, refreshing sleep.

QUESTIONS ON CHAPTER 44

1. What are the keys to the possession of sound health?
2. Describe the skin of the human body.
3. What is the purpose of sweat and oil glands?
4. Why do our bodies perspire?

5. Why should the skin of the whole body be washed regularly?

6. What caused the Great Plague of London in 1665?

7. What is the cause of some diseases of the skin?

8. Why should hair be brushed and washed regularly?

9. What danger arises from dirty finger nails?

10. Why is it important to brush the teeth regularly?

11. What kind of material should be worn next to the skin?

12. Explain why houses should be well ventilated.

13. Why do we need a varied diet?

14. Why are physical exercises an important factor in keeping the body healthy?

15. Explain why rest and sleep should be taken regularly?

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